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G. S. Marzot

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Bedford, Massachusetts

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Abstract:

This paper describes a computer program, NetStat, that is designed to analyze the connectivity of probabalistic networks. The program, which offers a full graphic user interface (GUI), allows the user to visually layout a network topology and specify the destruction probability, Pd, for each network element. A Monte-Carlo simulation is utilized to obtain estimates of various connectivity metrics. Some details of the implementation are discussed and an example application is illustrated. A user manual is provided. Source code is also provided, written in Symantec's Think Pascal for the Macintosh personal computer.

Acknowledgments:

I would like to acknowledge the contribution of Dr. B. D. Metcalf under whose direction the initial work on this simulation was performed. I would also like to acknowledge Dr. V. C. Georgopoulos who also participated in the previous study and whose insights I found valuable. I would like to thank Dr. N. P. Shein who provided me with the "Graph Theory" perspective on the problem as well as many fine reference texts. I would also like to express my appreciation to Prof. C. H. Chang and the Tuft's University Electrical Engineering Department for their support and supervision of this work. A special thanks to Hilary Marzot.

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1.0 Introduction:

The study of networks has found application in many diverse areas. These range from air-traffic routing, to power and commodity distribution, telecommunication and computer networks as well as epidemiology and circuit analysis. One quality which network designers/analysts are often concerned about is the degree to which the network elements or nodes are connected. In the case of supply networks or communication networks the system designer may want to provide reliable connection between two given nodes or a uniform level of reliable connection to all nodes. A network architect may also be faced with certain performance constraints such as delay and throughput which limit his ability to meet the other requirements. As is often the case, the cost and availability of components and technology further constrain the designer. In this demanding environment of tradeoffs it is desirable to be able to quantify the performance of a given network, including its connectivity, to determine when the design goals have been adequately met and to enable resources to be allocated in the most intelligent way.

Historically a great deal of work has been done on analyzing the reliability of networks under a deterministic threat environment; that is, assuming an attacker has complete fore-knowledge of the network topology[1][7][15]. The goal of this previous work often centered on minimizing the number of steps required to partially or completely segment a network, and a number of closed-form solutions have been derived[2][7]. This approach is reasonable given the assumption of a deterministic threat. The closed-form result is also practical in light of the fact that computer simulated solutions were not viable until only a relatively short time ago.

However, networks are often subject to random factors such as weather, component life time, and collateral damage, either due to benign (construction/car accident) or hostile (military attack on adjacent target) sources. In this environment it is natural for

network component reliability to be described in a probabalistic fashion, yielding probabalistic networks. Analysis of this type of network has been characterized as an "NP-hard problem" and closed form solutions become intractable for all but the most constrained problems[13].

It is the aim of the computer application described in this paper to provide the network designer/analyst with a tool to asses various aspects of connectivity for these probabalistic networks. It is also the goal of the tool to be easy to use and generally applicable to a wide array of real world problems. Therefore a number different types of network components are provided for problem setup. And several connectivity metrics can be computed allowing the analyst to answer several types of questions including: What topology is more reliable? Where is the best location for an additional link to enhance connectivity? How often should a given resource be replicated in a distributed computing environment? And more.

2.0 Theory of Operation:

To understand the operation of the tool, let's first define some vocabulary. The terms described here are defined primarily in the context of the tool but are also generally used in other contexts (see texts on Graph Theory for rigorous definition of terms[2][3]). A network is a collection of any number of nodes and links where N nodes can be joined by M links. A link must always be terminated by a node at each end (does not have to be a different node for a self-loop although self-loops are not considered here).

A link is represented as an edge or line which joins two nodes. There are two types of links considered here: simplex and duplex. Simplex links are directed edges which allow connection between nodes only in one direction. Duplex links are undirected edges which allow bidirectional connection between nodes. No distinction is made between half-duplex and full-duplex here.

Nodes are represented as points either located at the end of one or more links or separately as unconnected elements. Three types of nodes are considered here. The term node can be used generally to describe all types or specifically referring to the "Node" element in the computer application. The other node types in the application are "Hubs" and "Bypass Switches". "Hubs" only differ from the generic "Node" in a conceptual way and are treated by the application identically to "Nodes". "Hubs" are generally considered the central connecting elements in star type networks. They are included here as a separate type of element so that type specific parameters can be set for all hubs in a given network. The

"Bypass Switch" is another specialized node. It differs from the other nodes in that it is not considered when computing segment length or when assessing segmentation.

A segment is defined as a subset of the original network, consisting of nodes and links, within which each non-"Bypass Switch" node has a round trip path to every other non-"Bypass Switch" node. A network is considered segmented if it is made up of more than one segment. In other words, a network is segmented if at least one operational node is unable to establish a round trip path to at least one other operational node. Figure 1a and figure 1b illustrate this definition.

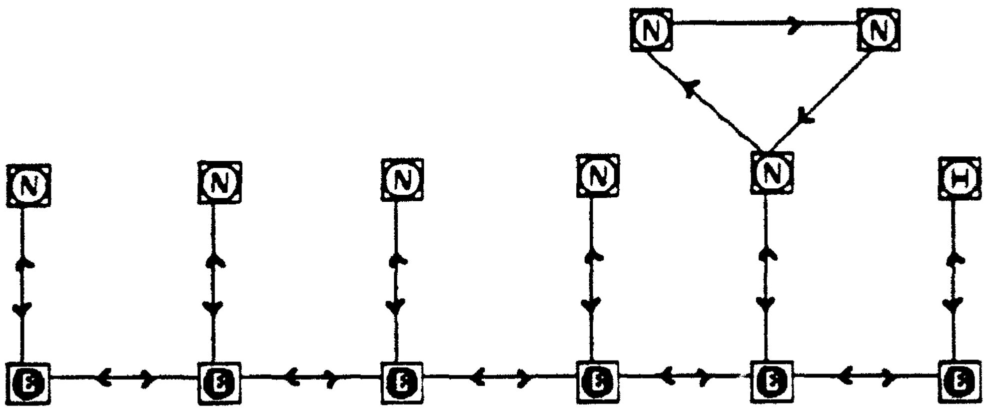

Figure 1a - An Unsegmented Network, the number of segments=1

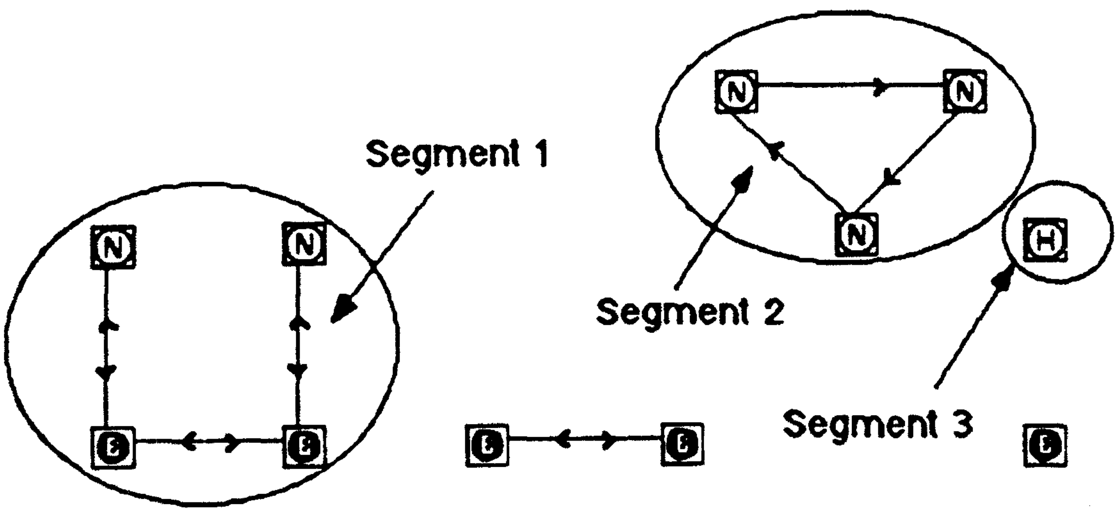

Figure 1b - A Segmented Network, the number of segments=3
Note: segments consisting of only Bypass Switches are not counted.

In a probabalistic network each network component is given a probability of failure or destruction, Pd. The element is considered to be either operative or inoperative based on a distribution described by Pd. This probability can also be thought of as the reliability of the component within an interval of time. Because each element in the network can assume a binary state it is apparent that in a network consisting of N nodes and M links that the total number of system states is given by:

$$\text{Nstates} = \#\text{of possible system states} = 2^{N+M} \tag{1}$$

It should be noticed that this number can be quite large, even for small to medium sized networks.

Each system state, consisting of some combination of operative and inoperative network components, has a certain probability of occurrence given by the following:

let x_j = *the event that a particular sytem state, j, occurs; where* $1 \leq j \leq \text{Nstates}$
p_i = the probability the the i^{th} element is inoperative; $q_i = 1 - p_i$
$\varepsilon_i = q_i$ *if the* i^{th} element in a particular system, j, is operative
$= p_i$ if the i^{th} element in a particular system, j, is inoperative
$P(x_j)$ = the probability x_j occuring

$$P(x_j) = \prod_{i=1}^{\substack{\#\text{of elements} \\ \text{in system } j}} \varepsilon_i \tag{2}$$

Given that the network is in one of these system states, with some nodes and links inoperative, the resultant topology can be analyzed for qualities like segmentation and segment size.

Now it is useful to describe the connectivity metrics investigated by NetStat. The primary measure of connectivity looked at by this tool is the probability of segmentation, Pseg. This metric is very simply the probability that the network will consist of more than one segment. Stated more rigorously, Pseg is the probability that at least one operational node cannot establish bidirectional connection with at least one other operational node. This is seen as a good measure of how well the network is performing its function of connecting all nodes and it is desirable that Pseg be minimized in most cases. This metric

is an accepted reliability measure in the current literature [11]. As a note, a network consisting of one or zero nodes is not considered segmented by definition. Pseg can be calculated as follows:

let $\rho_j = 1$ if the j^{th} system state contains > 1 segment

$= 0$ if the j^{th} system state contains 1 or 0 segments

$$\text{Pseg} = \sum_{j=1}^{\text{Nstates}} \rho_j P(x_j) \tag{3}$$

Another well accepted measure of connectivity which is investigated by NetStat is the expected value of the number of connected pairs, Ecp [4]. For a given network, the number of connected pairs is defined by:

let K_j = # of segments in the j^{th} system state

N_k = # of nodes in the k^{th} segment of the j^{th} system state

$$\text{\#of connected pairs in a particular system,j,} = \text{Ncp}_j = \sum_{k=1}^{K_j} \frac{N_k(N_k-1)}{2} \tag{4}$$

It is the number of ways to choose 2 nodes from a set of N nodes summed for each segment in the network. The expected value of connected pairs is given by:

$$\text{Ecp} = \sum_{j=1}^{\text{Nstates}} \text{Ncp}_j P(x_j) \tag{5}$$

Two other metrics are, the average or expected value of the segment length, Esl, and the expected value of the maximum segment length, Emsl. All possible segments and their probability of occurrence are used to compute the average segment size; whereas only the maximum segment length for each system state and it probability of occurrence is used to compute the expected maximum segment length. These measures give an idea of how well the network is held together even if segmentation does occur. They also give an indication of the most likely segment size which is useful when designing distributed systems on a probabalistic network. Their definition is stated mathematically as follows:

let L_k = the length of the k^{th} segment

M_j = the length of the maximum segment in the j^{th} system state

$$\text{Esl} = \sum_{j=1}^{\text{Nstates}} \left(\frac{\sum_{k=1}^{K_j} L_k}{K_j} \right) P(x_j) \quad ; \qquad \text{Emsl} = \sum_{j=1}^{\text{Nstates}} M_j P(x_j) \tag{6)(7}$$

For generality, when we look at Ecp it is normalized to the maximum number of connected pairs in the fully functional network. Similarly, Esl and Emsl are normalized to the total number of nodes in the whole system when all nodes are functional.

All of the metrics here can be computed exactly based on their definitions. One could examine every possible state of the network along with its probability of occurrence and keep track of segmentation , number of connected pairs, segment size etc. However, as stated before, the number of system states grows exponentially with the number of nodes and links and this method would be intractable for all but the most trivial networks.

Another approach, which works in some cases, takes advantage of system constraints and network symmetries to simplify the computation. Two of these analytical, closed-form expressions are shown here without proof for later comparison. The first is an expression for Pseg for an N node ring with duplex linking elements. The parameters are p, the node probability of failure, and q, the duplex link probability of failure:

$$Pseg = 1 - p^N + (N-1)(1-p)^N(1-p)^N - N\sum_{j=0}^{N-1} p^j(1-p)^{N-j}(1-q)^{N-j-1} \qquad (8)[8]$$

The second is an expression for Pseg for an N node simplex ring, where q is the simplex link probability of failure:

$$Pseg = 1 - p^N - N\,p^{N-1}(1-p) - (1-q)^N(1-p)^N \qquad (9)[12]$$

However, when the system under consideration has a fair sized number of nodes and a fairly complex topology, our only recourse is computer simulation. The technique used in NetStat is a Monte-Carlo simulation. The basic principal of the Monte-Carlo technique in this application is to randomly generate an ensemble of the system states so that estimates of the connectivity metrics can be computed over this ensemble. It is an essential requirement that the randomly generated system states in the Monte-Carlo simulation be statistically independent. This can be achieved if a random number, Rn, uniformly distributed between 0 and 1, is generated for each network component and compared to that components Pd in the manner of a Bernoulli experiment, as follows:

if $Rn \le Pd_i$, the state of the i^{th} element is inoperative
else if $Rn > Pd_i$, the state of the i^{th} element is operative

This also assumes that the uniform random numbers are statistically independent. This process is repeated for every element in the network thus generating one random state of the network.

The randomly generated system state can then be analyzed as before for segmentation, number of connected-pairs, segment size, etc. This process of generating a state and analyzing it is repeated as many times as is dictated by the simulation. The idea is that the statistics observed in this randomly generated ensemble will reflect the true ones and a good estimate of our metrics will be obtained if enough samples are used.

The benefit of the Monte-Carlo technique is that the number of states or trials that must be investigated can be significantly less than the total number of system states and is only dictated by the required accuracy. There is an expression which relates the number of Monte-Carlo trials required to the desired accuracy as follows. Without going into detail this expression relates the estimated result produced by the simulation to the exact result it reflects with the number of trials, N, as a parameter. It can be applied to general precision if the exact probability, p, is assumed to be the least significant digit in the desired accuracy:

p = the exact probability being estimated

$\hat{p}$ = the estimated probability

$$p - 2\sqrt{p/N} \le \hat{p} \le p + 2\sqrt{p/N} \qquad (10)[6]$$

This expression is valid with a 95% confidence level due to certain approximations in its derivation. An example of its application follows:

let p = the desired accuracy in Pseg = 10^{-3}

N = #of Monte-Carlo trials = 10^4

$$\therefore \quad 0.00036 \le \hat{p} \le 0.00163$$

From this we can expect to see fluctuation in the third decimal place and occasional fluctuation in the second decimal place when 10,000 Monte-Carlo trials are used.

3.0 Implementation:

The computer application, NetStat, was implemented on a Macintosh personal computer using Symantec's Think Pascal. The Macintosh platform was desirable due to its

inherent support for a graphical user interface as well as being an adequately powered computing engine. This support comes primarily through the, roughly, 700 ROM-based Pascal routines which are bundled with the Macintosh computer. These routines handle a wide array of low level tasks, including the creation of a windowing environment, pull-down menus, file I/O, basic drawing, etc. Although the description of the program which follows is focused primarily on the simulation related data structures and algorithms, it should be noted that more than 70% of the source code is devoted to creating the GUI and platform specific interaction. This is a typical percentage for applications with a full GUI.

The application was geared to the high end Macintosh II series computer (SE/30 also) which incorporates a separate math coprocessor to enhance the efficiency of floating-point operations. The source code may be recompiled to run on Macintoshes without a math coprocessor making minor adjustments. However this will result in a noticeable degradation in performance.

The choice of a Pascal-based development environment* was natural due to its compatibility with the operating system interface and the language's straightforward readability. Pascal also offers a number of language constructs which facilitate the implementation of this model. These include; abstract data structures such as "records" and "sets", the ability to link structures with pointers (e.g., linked list), and support for recursive procedure calling. In the description of the program implementation that follows it will be shown how these features were utilized to construct a model of the network and facilitate its analysis.

A typical user session on NetStat consists of three phases (see NetStat User's Manual for complete description of program environment and user interface). The three phases are; topology construction, parameter specification, and simulation run. During the topology construction phase, while the user visually lays out the network to be analyzed, an analogous data structure is constructed and held in the program's global data space. The data structure is basically a linked list consisting of two types of elements, node records and link records. Figure 2 shows the basic makeup of these two records (see NetStat Source Code, ConsVars Unit for exact record structure).

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*Authors Note: The Think Pascal environment is an excellent full featured professional programming environment. It offers an integrated editing, debugging, linking and compiling shell with an intuitive and easy to use interface. I highly recommend it.

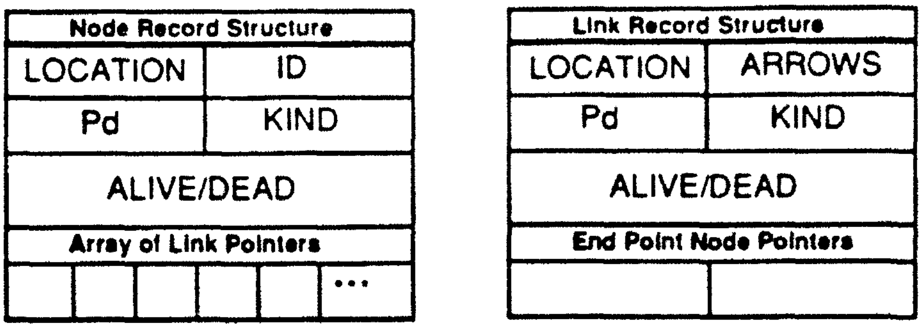


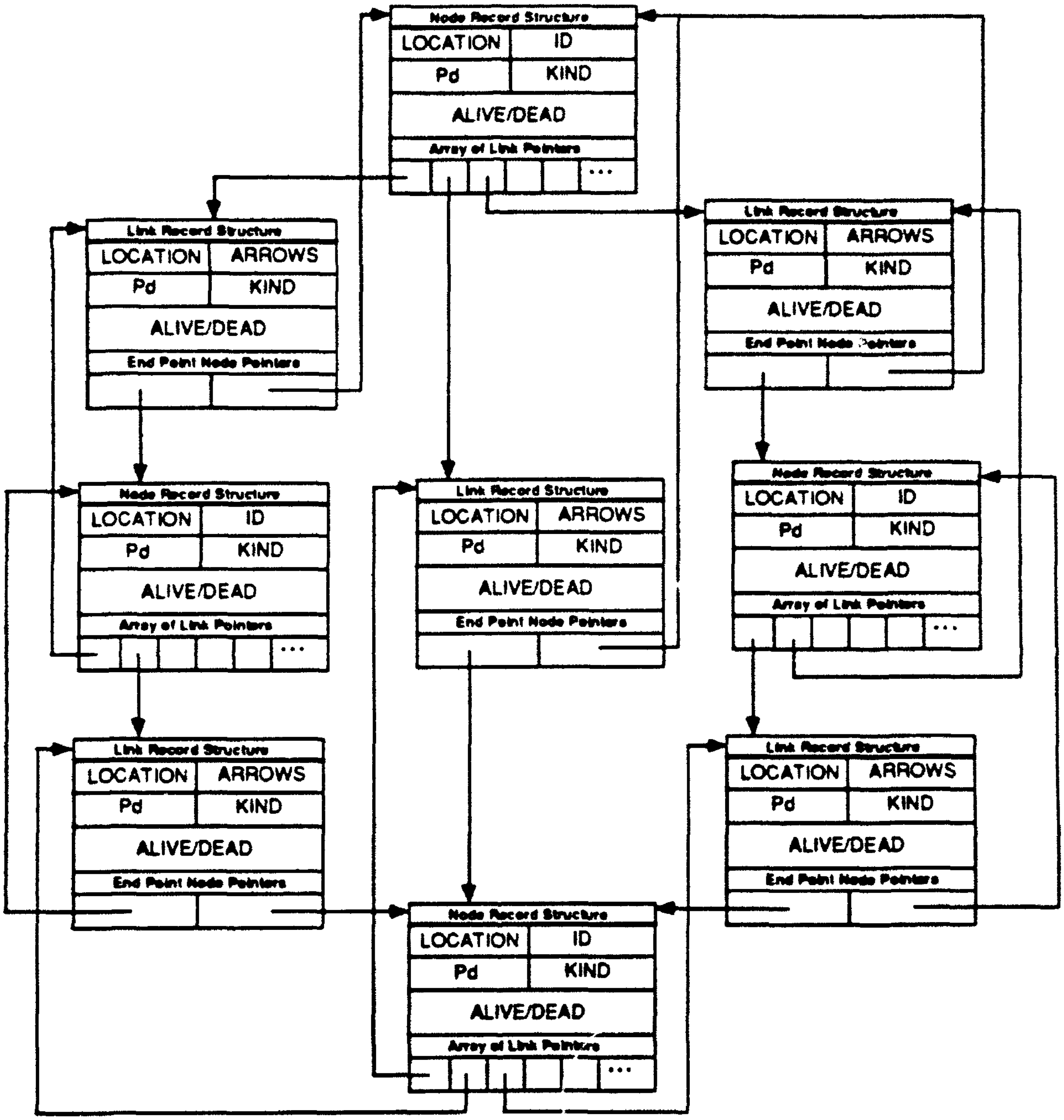
Figure 2 - Record Structure for Nodes and Links

The network element records contain graphical information such as the "location", which specifies, relative to the application drawing pad,where the element should be drawn. In the case of the link, additional information is stored showing where the "arrows" should be drawn. All elements have a "Pd" field which is its probability of failure and a "kind" field which specifies "Node","Hub", or "Bypass" in the case of the node element and "Simplex" or "Duplex" in the case of the link. All elements also have a state field which specifies whether the element is operational or not. Most significantly, all element records have holders which can contain the address of, or pointers to, the other records in the network data structure. In the case of the nodes, an array of pointers to link records is used to keep track of which links emanate from a node. It should be noted that a pointer to a bidirectional link would be stored in the array of both its endpoint nodes whereas a simplex link pointer would only be stored in the node from which it emanates as indicated by its arrow. In the case of links, two fields are provided to keep track of the addresses for the two node records at each endpoint.

Figure 3 illustrates the resultant data structure when a 4 node ring with one diametric crosslink is constructed. All links are bidirectional.

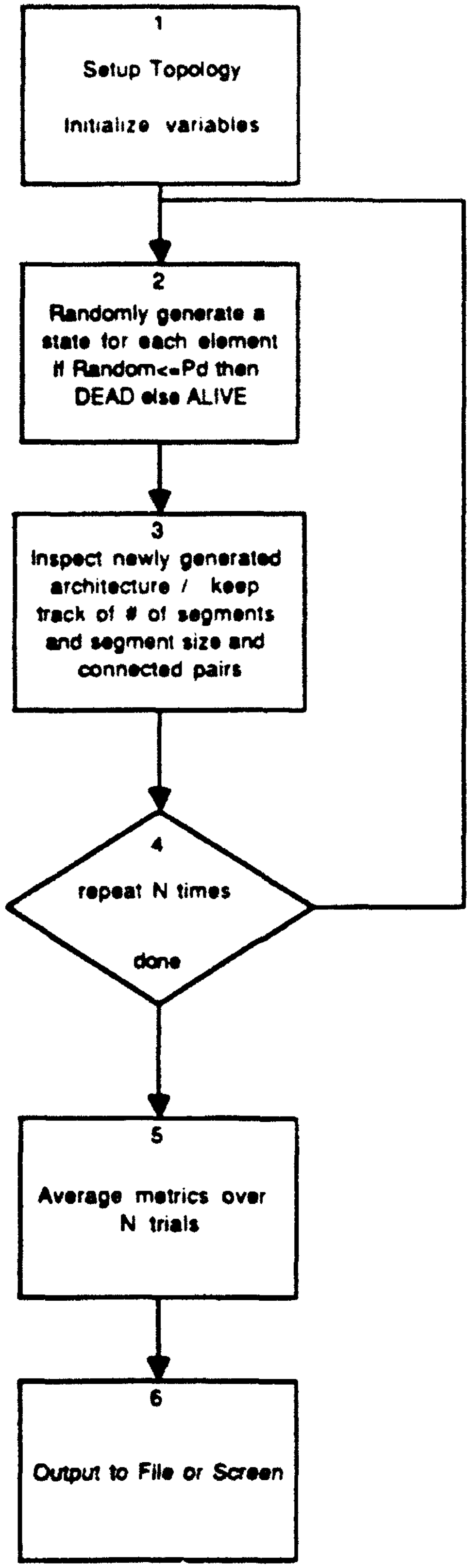
After the topology is constructed the user may specify the Pd's for the network components. This may be done uniformly by type; that is for instance, all "Hubs" have a Pd = 0.1. It may also be done individually by visually navigating the network (clicking on components) and setting each components Pd accordingly. Additionally, parameters such as the number of Monte-Carlo trials can be set.

When parameters such as these are set up, a simulation "run" can commence. A flow chart of the simulation operations is shown in figure 4. The state of each network component is determined for all the components in the network to produce a new topology or system state. This resultant topology is analyzed for the metrics described above and counters are maintained as to whether segmentation occurred, the number of segments



Pascal Data Structure Representing Network of Nodes and Links

Figure 3



Flow Chart for Monte-Carlo Analysis of Network Topology

Figure 4

produced and their sizes. This process is repeated N times where N is the number of Monte-Carlo trials. Then the counters are examined to determine Pseg, Ecp, Esl and Emsl.

The operations in block 3 of figure 4 are central to the working of the simulation and it is very important that this step be computationally efficient. Basically, this operation is implemented as a depth-first tree search which proceeds until all operational nodes are accounted for. The searching portion of code is called recursively while keeping track of "set" type variables which indicate which nodes are in the current segment and those that are accounted for in other segments (see NetStat Source Code, MultiEngine Unit, procedure inspectseg). The "set" language constructs included in Think Pascal are instrumental in these operations, providing a means to compute rapidly the union and intersection of various sets. The tree search must treat simplex links in a special way. The nodes encountered when traversing a simplex link are not added to the set of nodes in the current segment until a roundtrip path is established.

Another critical portion of the implementation is the nature of the random numbers generated when determining the state of each network component. These numbers must be statistically independent and a unique series of numbers must be generated each time a simulation is run. The random number generator used in this simulation is the native one found in the Macintosh ROM which has been well studied and determined to generate high quality output*. Steps were taken to re-seed the random number generator between runs.

Source code for NetStat is included at the end of this paper. The code is broken into three units; ConsVars, Main, and Multi-engine. ConsVars contains global constants and global variables as well as application specific data types and structures. The "Main" unit contains many routines to implement the user interface and construct the network data structure as well as the main-line of the program. The "MultiEngine" unit contains two versions of the code that analyzes a given topology, one which is optimized for Pseg and another which is more general in scope.

* Minimal Standard RNG - Park, Miller; Communications of the Association for Computing Machinery. Oct. 1988

4.0 Example Application:

To illustrate how NetStat can be used an example problem is posed. The example problem, which might be faced by a local area network designer, is the choice between two given topologies. Specifically, the tool will be used to evaluate the benefits of a star topology versus a ring topology for a twelve node network. For one of the given topologies the tool will also be used to determine the best way to enhance its reliability.

Some assumptions about the problem follow. The role that the network is designed to fulfill is the bidirectional communication between all nodes, and the network is considered failed if all nodes cannot communicate. The link medium is assumed to be bidirectional (duplex) such as ethernet coaxial cable. For the most part, equivalent resources are available in each case. That is, twelve nodes and twelve links are available to construct the network. In the case of the star however, an extra component is assumed for the central connecting node, or hub. (In the actual simulation a "bypass switch" is used because we do not want the central node counted for Pseg or segment length - see Users' Manual). In general we know very little about the actual destruction probabilities for the various components. We have made the assumption that all components of one type have the same destruction probability. Additionally in certain design environments the nodes are more likely to fail than the links. This assumption has been made for one of the comparisons described here.

Figure 5a and 5b show the two architectures as they were set up in the simulation environment. The probability of segmentation was chosen as the criterion of optimization because of its stringent nature and because of the previously stated goal of the network to provide communication to all nodes. As a reminder, our aim is to choose the topology which minimizes Pseg. Since we have very little information about the probabilities of failure, we must analyze the behavior of the network over a range of values for each component, thus generating a family of curves for each topology which paint a broad picture of their respective levels of connectivity. The main parameters to be varied are the probability of destruction for the nodes (NPd) and for the links (LPd). In the case of the star the central nodes destruction probability (HPd) may also be varied. Figure 6 and 7 show families of curves of Pseg versus LPd for different values of NPd, for the ring and the star architectures respectively. It turns out that the Pseg for the star is fairly sensitive to the value of HPd (see Figure 8). For the purpose of comparison we

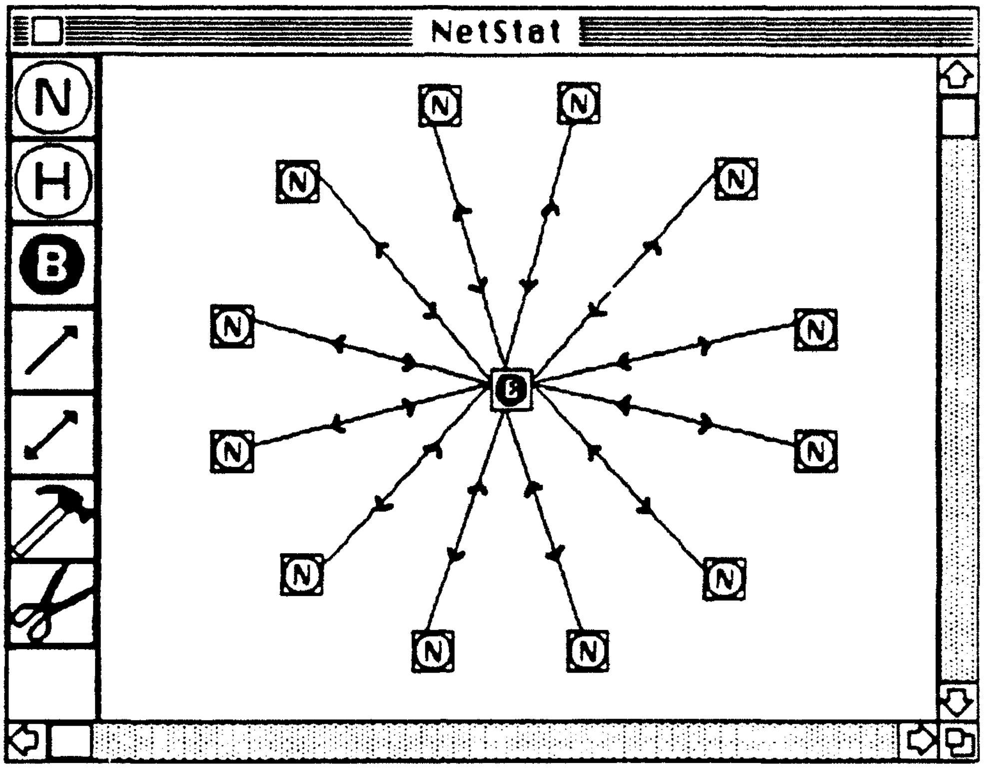


Figure 5a - Star Topology

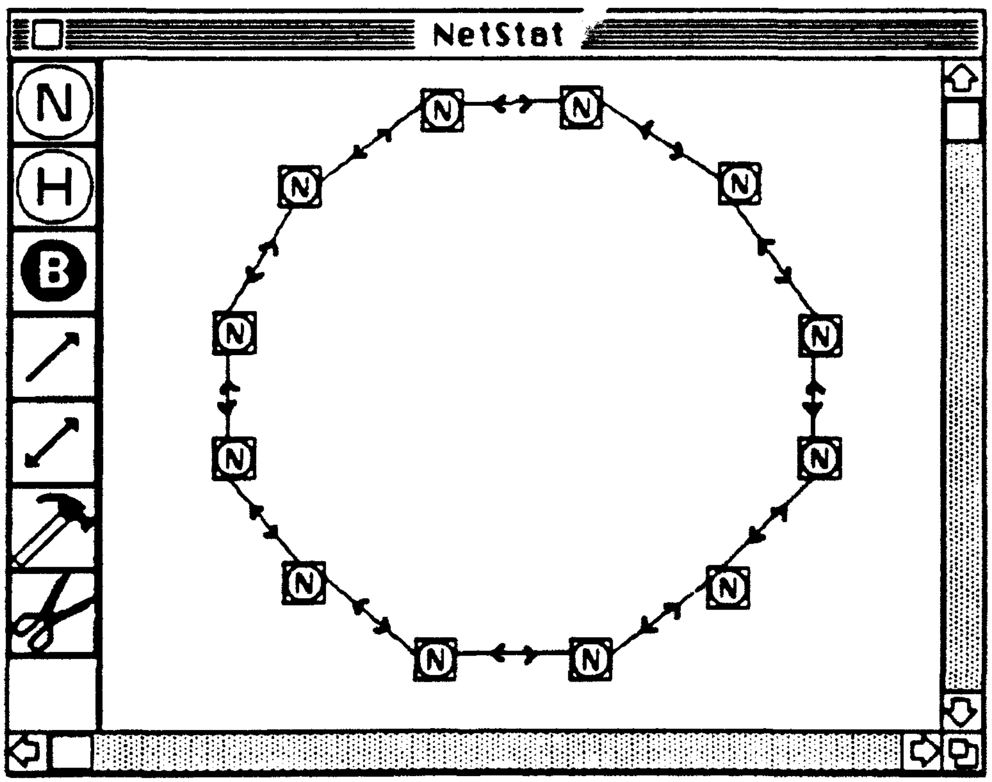


Figure 5b - Ring Topology

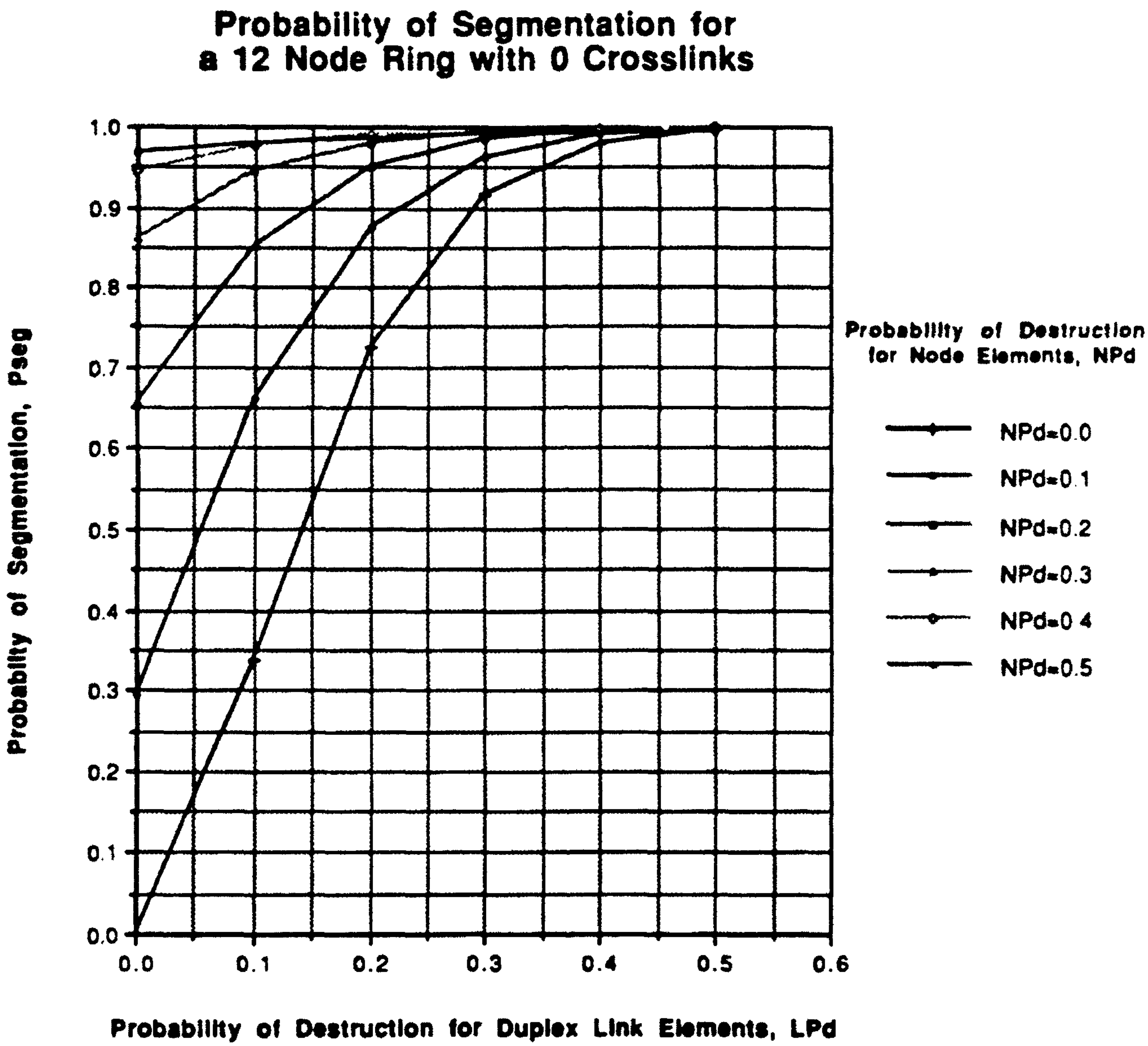
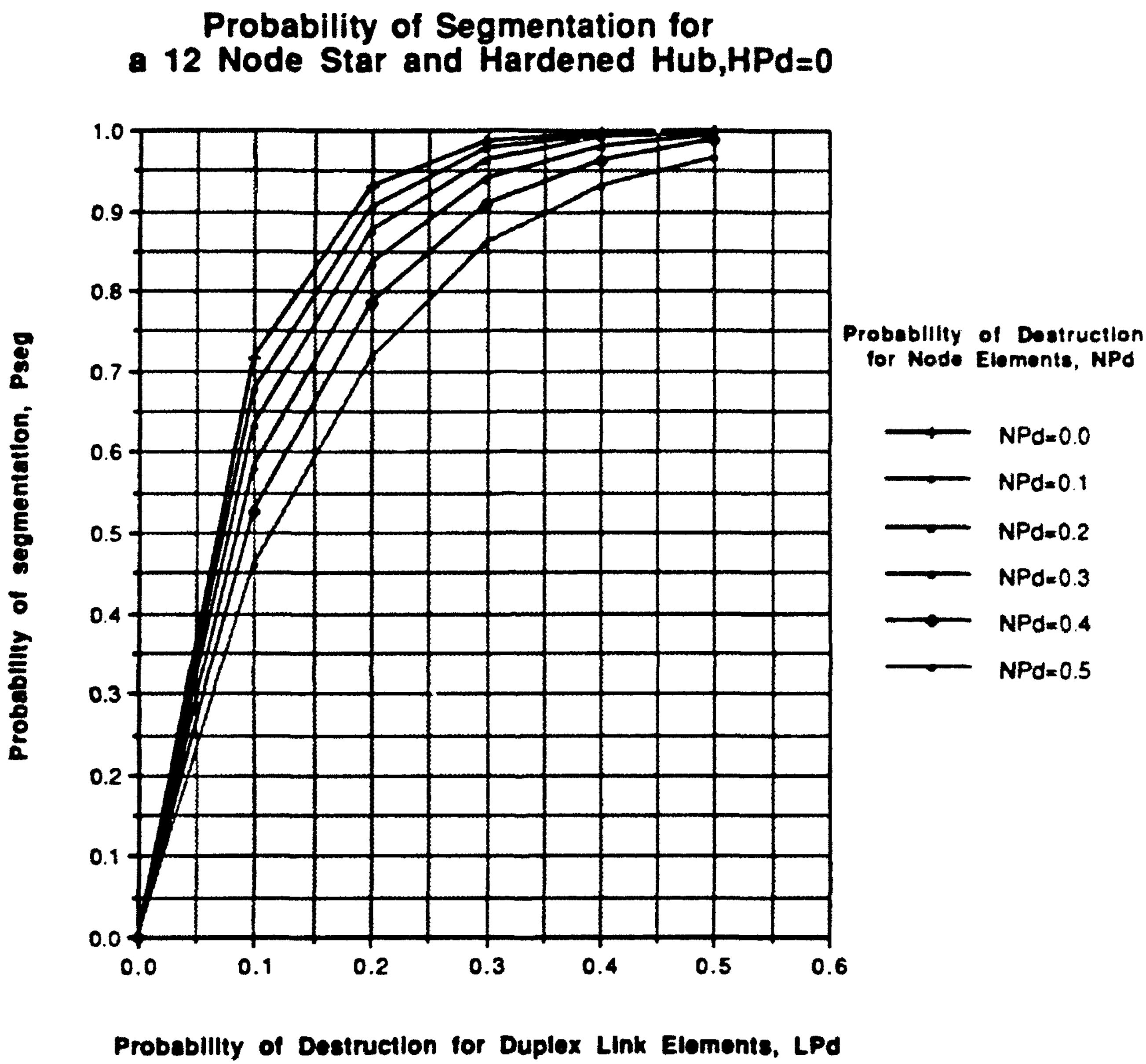

Probability of Segmentation for
a 12 Node Ring with 0 Crosslinks
Probability of Segmentation, Pseg
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction
for Node Elements, NPd
NPd=0.0
NPd=0.1
NPd=0.2
NPd=0.3
NPd=0.4
NPd=0.5

Figure 6


Probability of Segmentation for
a 12 Node Star and Hardened Hub,HPd=0
Probability of segmentation, Pseg
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction
for Node Elements, NPd
NPd=0.0
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NPd=0.2
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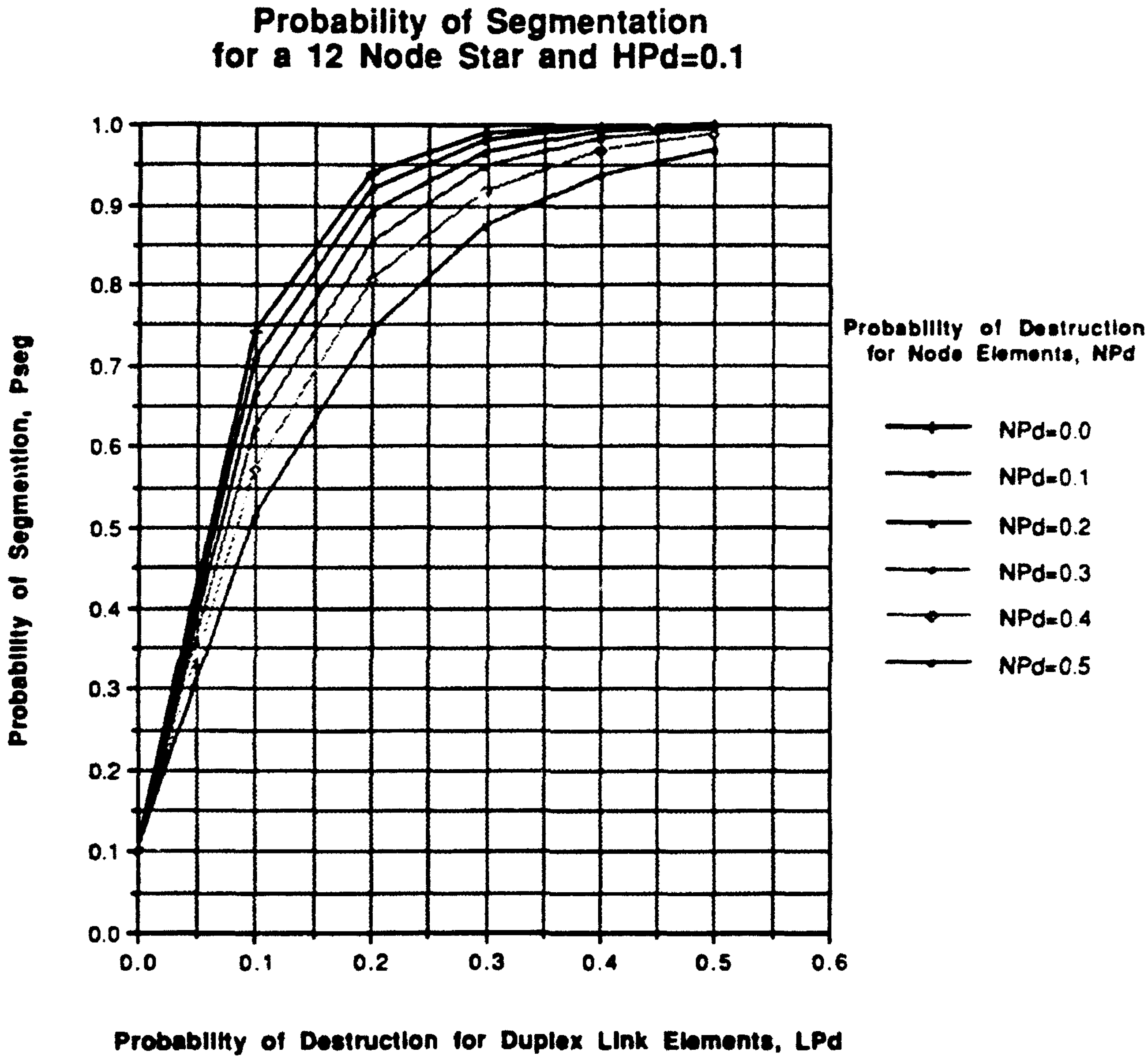
NPd=0.4
NPd=0.5

Figure 7



Probability of Segmentation
for a 12 Node Star and HPd=0.1
Probability of Segmentation, Pseg
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction for Node Elements, NPd
NPd=0.0
NPd=0.1
NPd=0.2
NPd=0.3
NPd=0.4
NPd=0.5

Figure 8

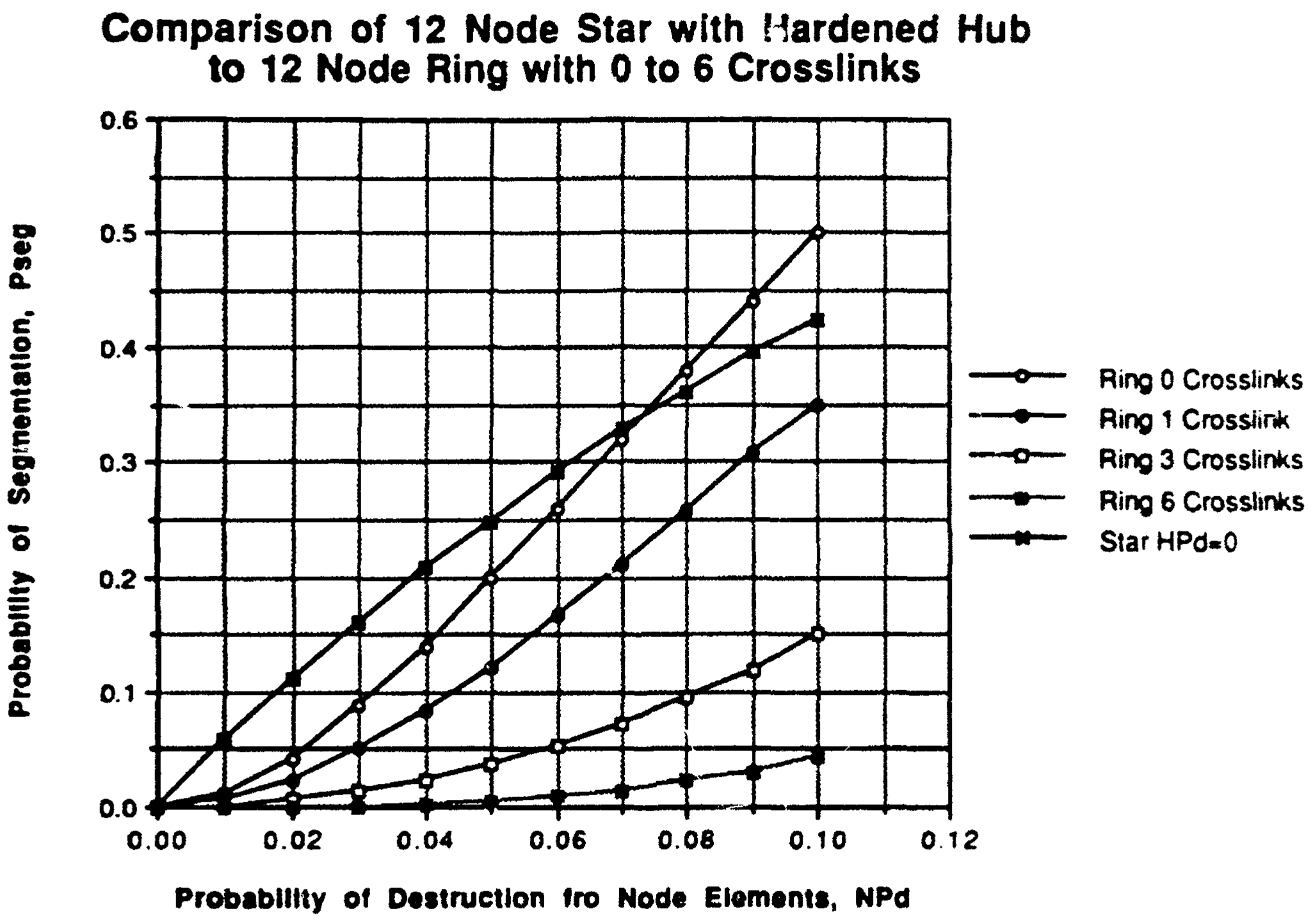
only examine two cases, HPd=0 and HPd=0.1, assuming a highly reliable hub can be used.

From the figures we can see that the stars reliability is more sensitive to LPd than to NPd, whereas the rings reliabili:, is more equally sensitive to NPd and LPd. Because we know that nodes are more likely to fail than links, we would like to make a comparison with this constraint. We can (somewhat arbitrarily) let LPd = 0.5 NPd and let NPd be varied. Figure 9 shows this for the star and ring. Also shown in this figure is the affect of adding crosslinks to the ring which will be discussed later. For all of the curves presented, failure probabilities beyond 0.5 were not investigated since the state of the network is less interesting when more than half of the components are removed (we assume that the network will almost assuredly be unusable in this state). Additionally, the value of Pseg approaches 0 as NPd approaches 1, by definition. This is somewhat counter intuitive and is not constructive in the comparison.

In the last comparison only failure probabilities less than 0.1 were examined. This assumption of low levels of component failure can be reasonable in many cases, excepting possibly the military environment where high levels of damage can occur. The comparison in Figure 9 favors the ring over the star even with the generous assumption of HPd = 0.

Given that a ring has been chosen, one may be interested in ways to enhance its reliability. There are two ways to approach this. The first is to try to minimize the failure probabilities of the components and the other is to add resources, namely links, to provide redundant connection. Assuming that all has been done to minimize failure probabilities we must turn to the addition of links. This begs the question; where should this link be placed to minimize the probability of segmentation. In the case of the twelve node ring an additional link was added between all possible pairs of nodes and it was determined that the diametric crosslink provides the most additional reliability. Data was generated for the ring with increasing number of diametric crosslinks. The results are shown in figure 9 through 13. From these figures we can see the significant benefit to reliability realized by adding redundant links.

It is also important to note that this has a greater impact on reliability than increasing the reliability of the hub in the star network. This is a significant result because it is often cheaper to add more links than to increase the reliability of certain components.



Comparison of 12 Node Star with Hardened Hub to 12 Node Ring with 0 to 6 Crosslinks
Probability of Segmentation, Pseg
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.00
0.02
0.04
0.06
0.08
0.10
0.12
Probability of Destruction fro Node Elements, NPd
Ring 0 Crosslinks
Ring 1 Crosslink
Ring 3 Crosslinks
Ring 6 Crosslinks
Star HPd=0

Figure 9

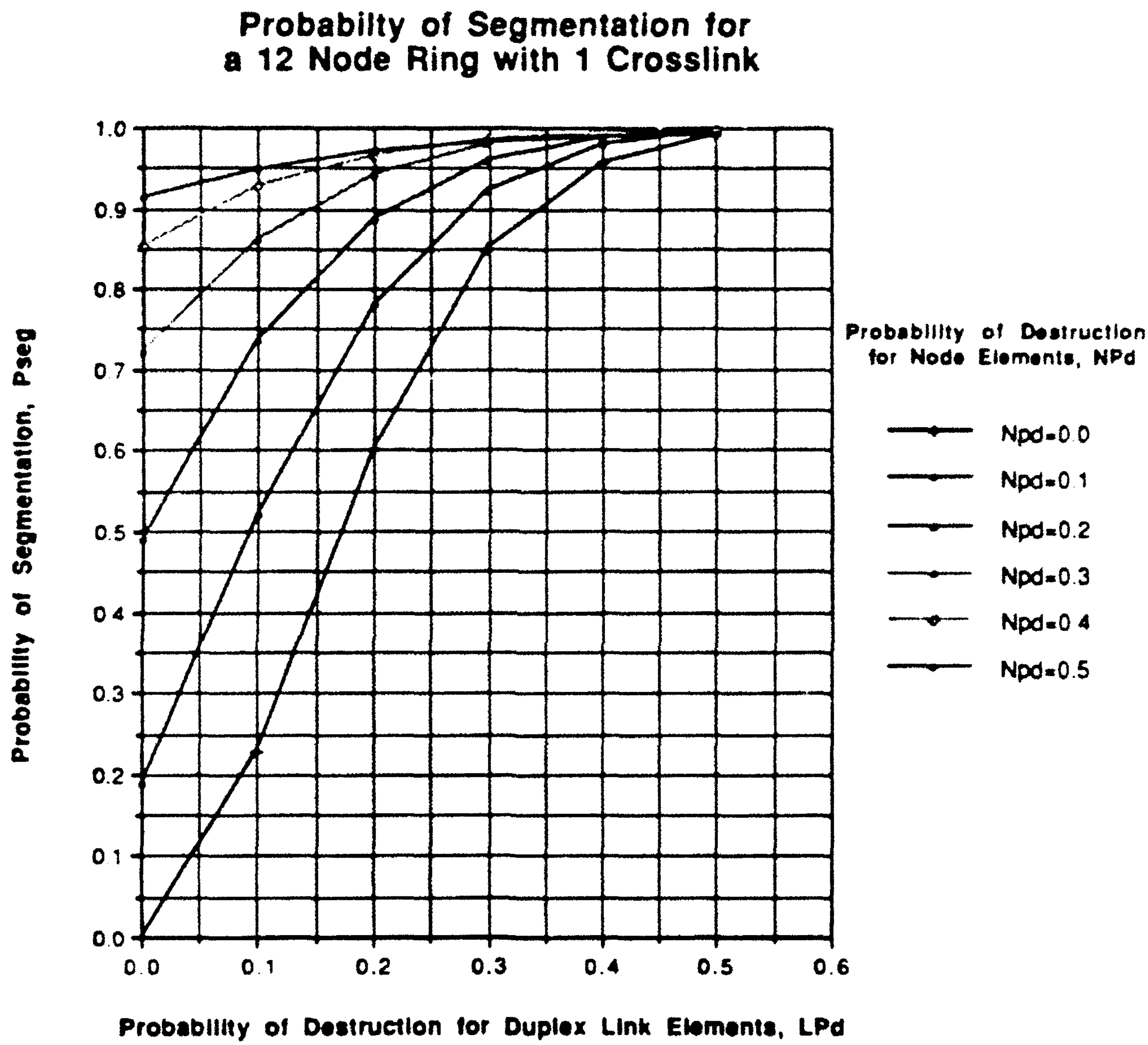

Probabilty of Segmentation for
a 12 Node Ring with 1 Crosslink
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Segmentation, Pseg
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction
for Node Elements, NPd
Npd=0.0
Npd=0.1
Npd=0.2
Npd=0.3
Npd=0.4
Npd=0.5

Figure 10

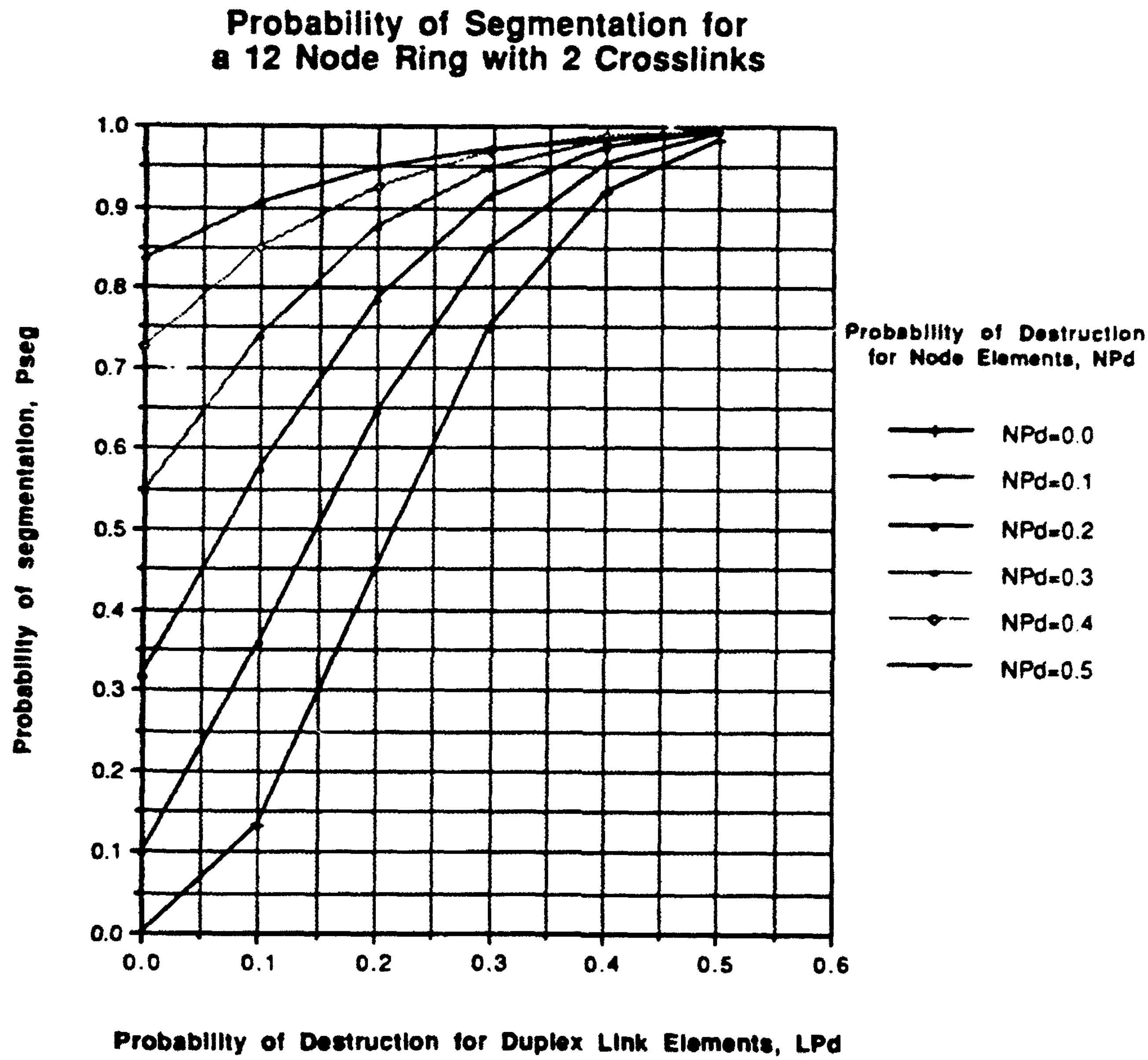

Probability of Segmentation for
a 12 Node Ring with 2 Crosslinks
Probability of segmentation, Pseg
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction for Node Elements, NPd
NPd=0.0
NPd=0.1
NPd=0.2
NPd=0.3
NPd=0.4
NPd=0.5

Figure 11

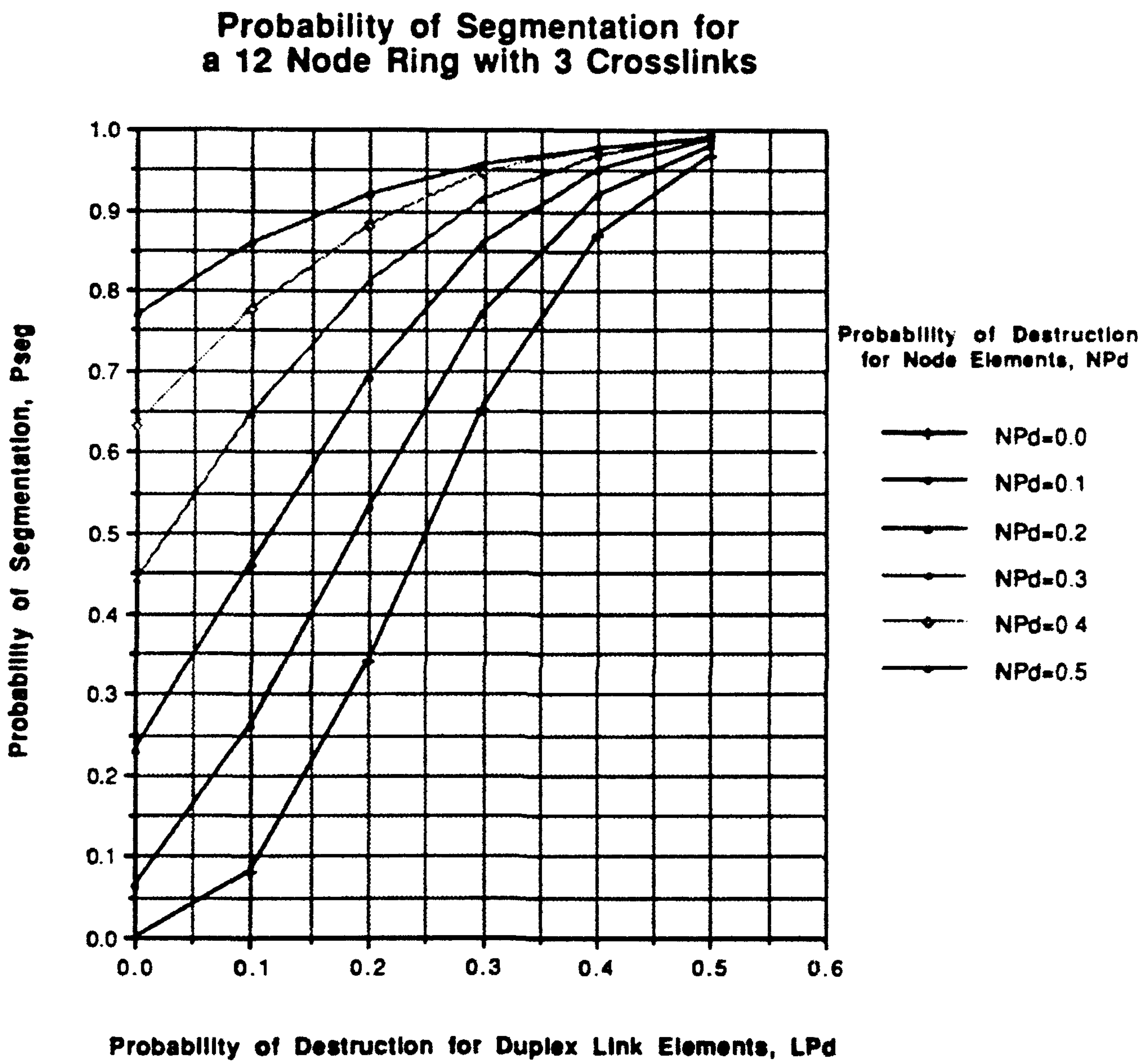

Probability of Segmentation for
a 12 Node Ring with 3 Crosslinks
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Segmentation, Pseg
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction
for Node Elements, NPd
NPd=0.0
NPd=0.1
NPd=0.2
NPd=0.3
NPd=0.4
NPd=0.5

Figure 12

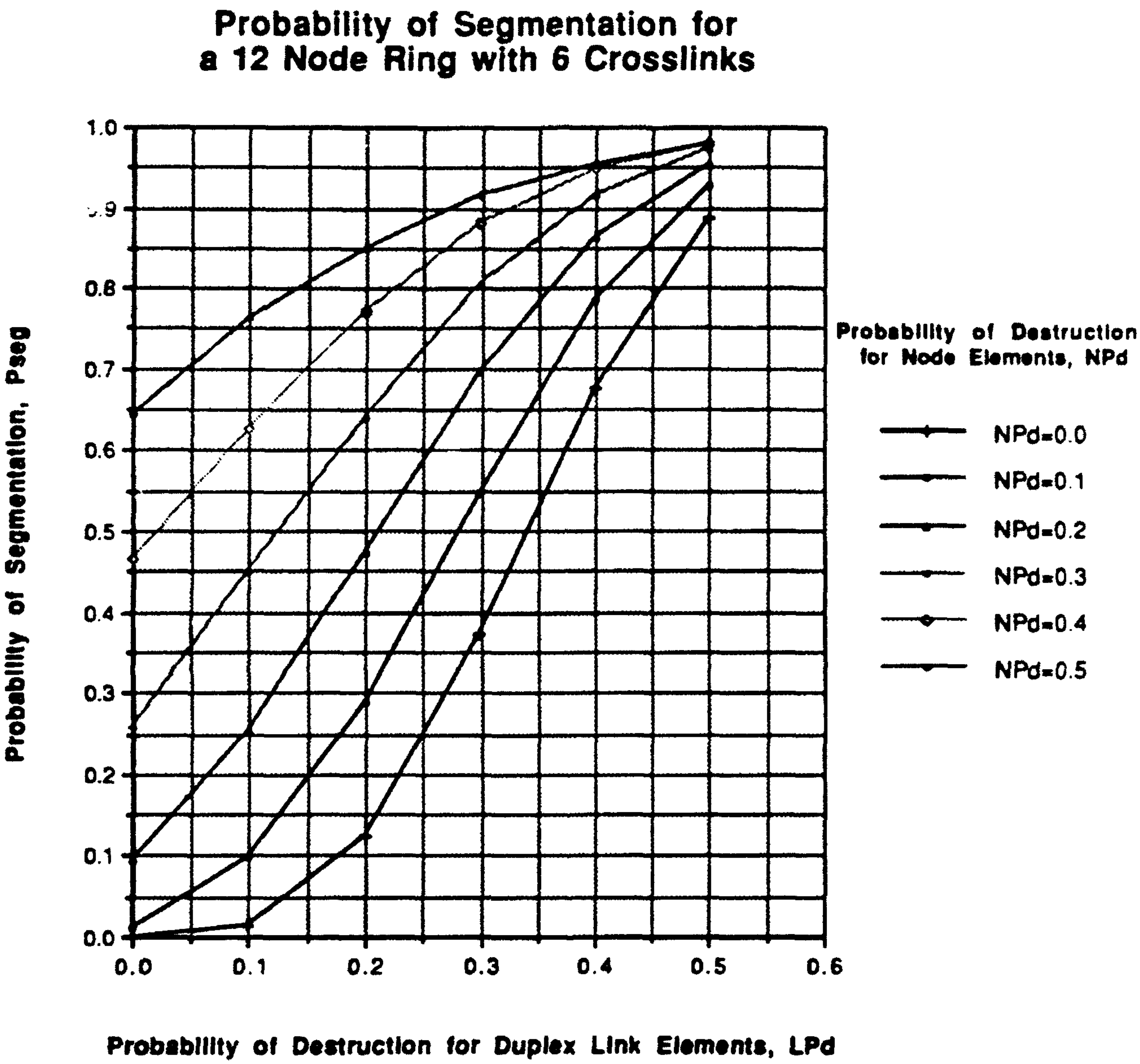

Probability of Segmentation for
a 12 Node Ring with 6 Crosslinks
1.0
.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Probability of Segmentation, Pseg
Probability of Destruction for Duplex Link Elements, LPd
Probability of Destruction
for Node Elements, NPd
NPd=0.0
NPd=0.1
NPd=0.2
NPd=0.3
NPd=0.4
NPd=0.5

Figure 13

5.0 Verification of Results:

One of the inherent problems with a simulated result obtained in the absence of a closed form solution, is the difficulty in verifying the output. Even when the principal of operation is sound, algorithmic errors can corrupt the results . Therefor it is necessarily to take extra steps to validate a simulation . In the case of the simulation described her , several techniques were used to gain confidence and corroborate the results.

One technique that is useful is to look at limiting cases. Specifically, we can look at the probability of segmentation as the Pd of the components approaches zero or one. Pseg should approach zero as component failure probabilities approach zero(provided the network was unsegmented to begin with). Pseg should also approach zero as the Pd of all the components approaches one, as stated before. This method can be applied to all components or selected ones. Another verification scenario using this technique is a star network where all the satellite nodes and links are given a Pd of 0 and the HPd is allowed to vary. As HPd approaches 0, Pseg approaches 0. In fact, Pseg should be exactly equal to HPd at all values.

Another technique is to examine simple cases with a few number of nodes and links. These can be worked out by hand and compared to the simulated result. Taking this a step further, closed form solutions that have been derived for certain types of networks (see Theory of Operation) can be compared to the simulated result. To add further confidence the comparison should be made for varying number of nodes and probabilities of destruction. This type of comparison was performed for the two closed form solutions provided earlier(equ. (8) and (9)) with positive outcome. Figure 14a and 14b show the results of the comparison.

Another aspect of the simulation that can be verified is the convergence of the Monte-Carlo results with increasing number of trials. This technique was applied to a sample network by examining the spread of the computed result for Pseg over a set of 10 runs with the number of Monte-Carlo trials varying from 10 to 100000. The results of this test are shown in figure 15. The performance is in agreement with that predicted by the expression for Monte-Carlo confidence intervals (equ. (10)).

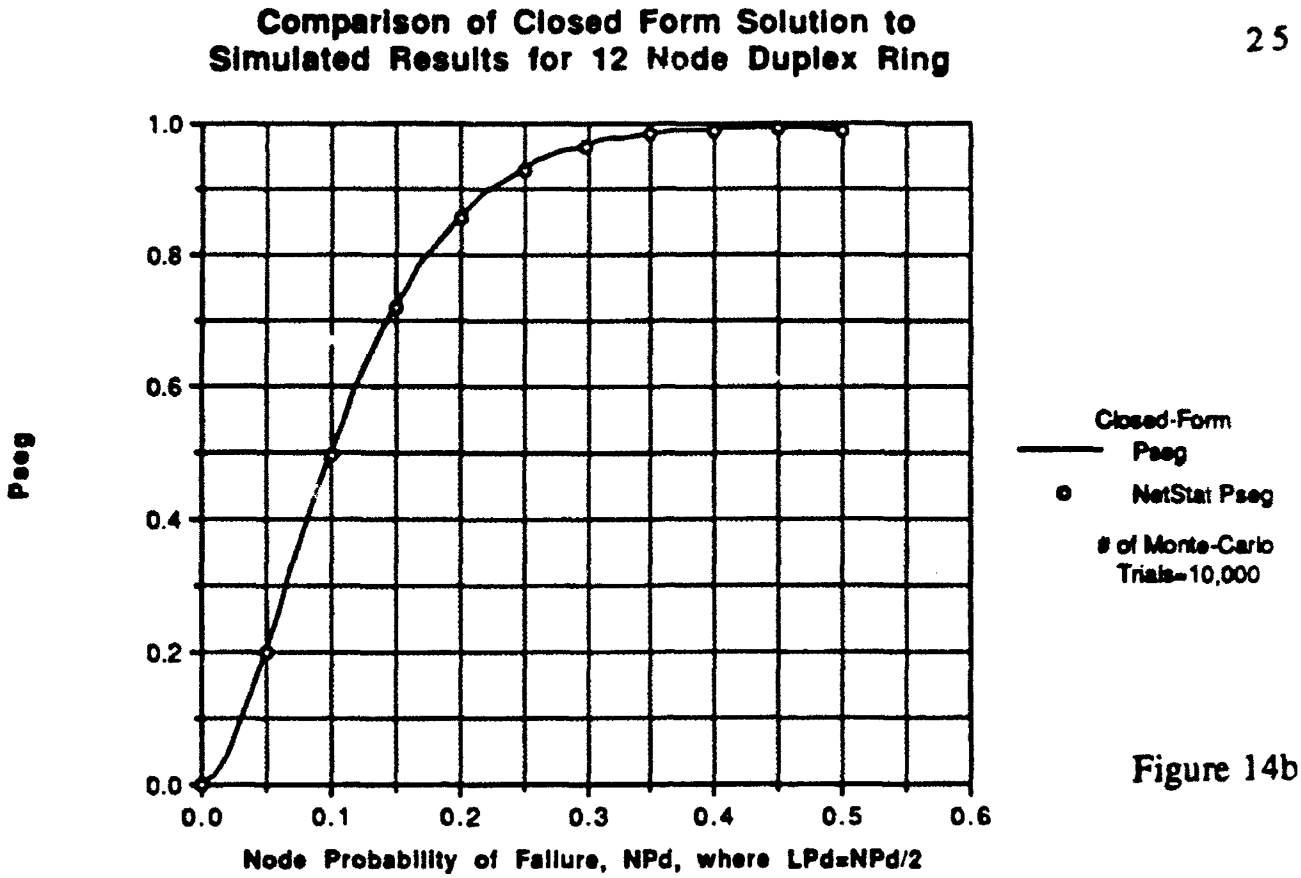


Figure 14b

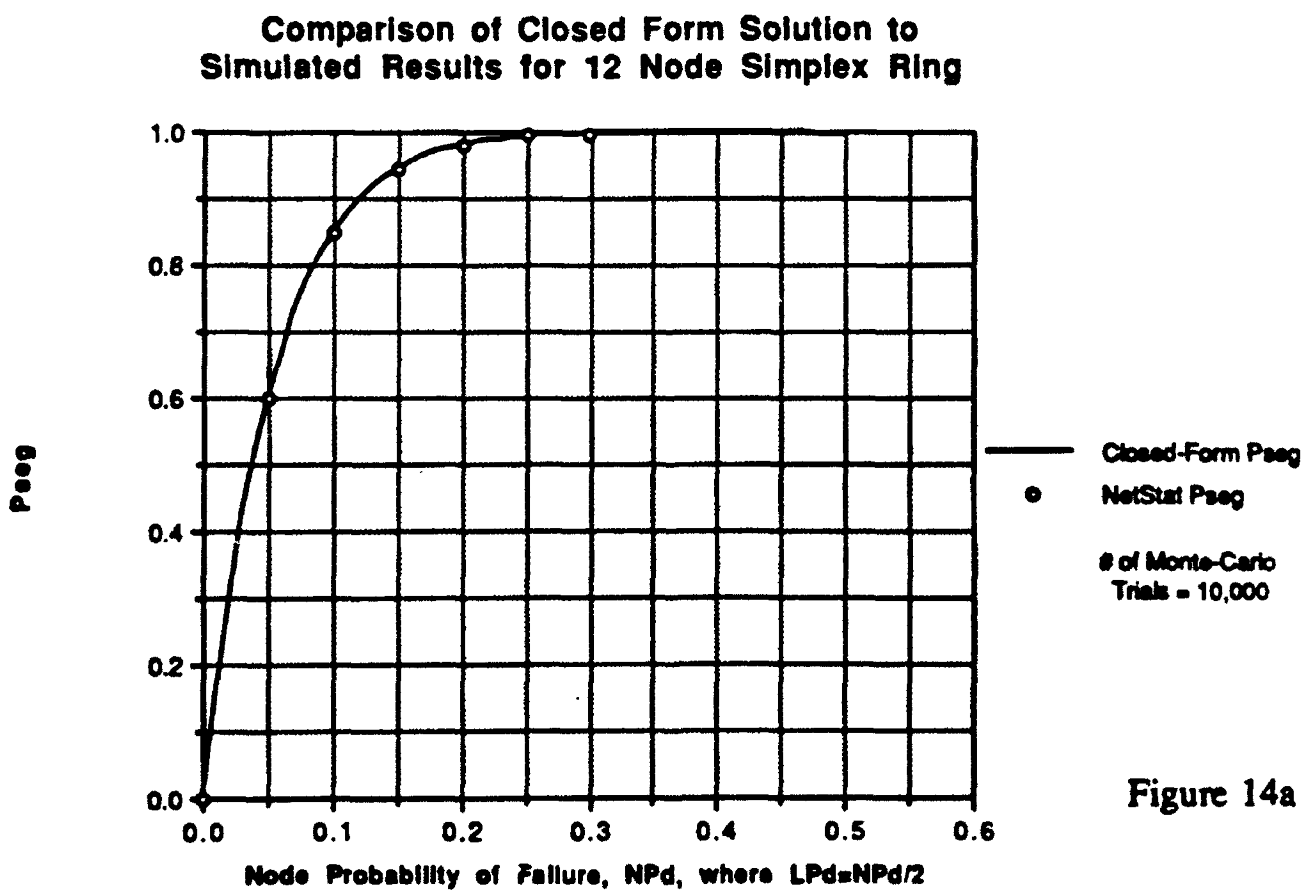


Figure 14a

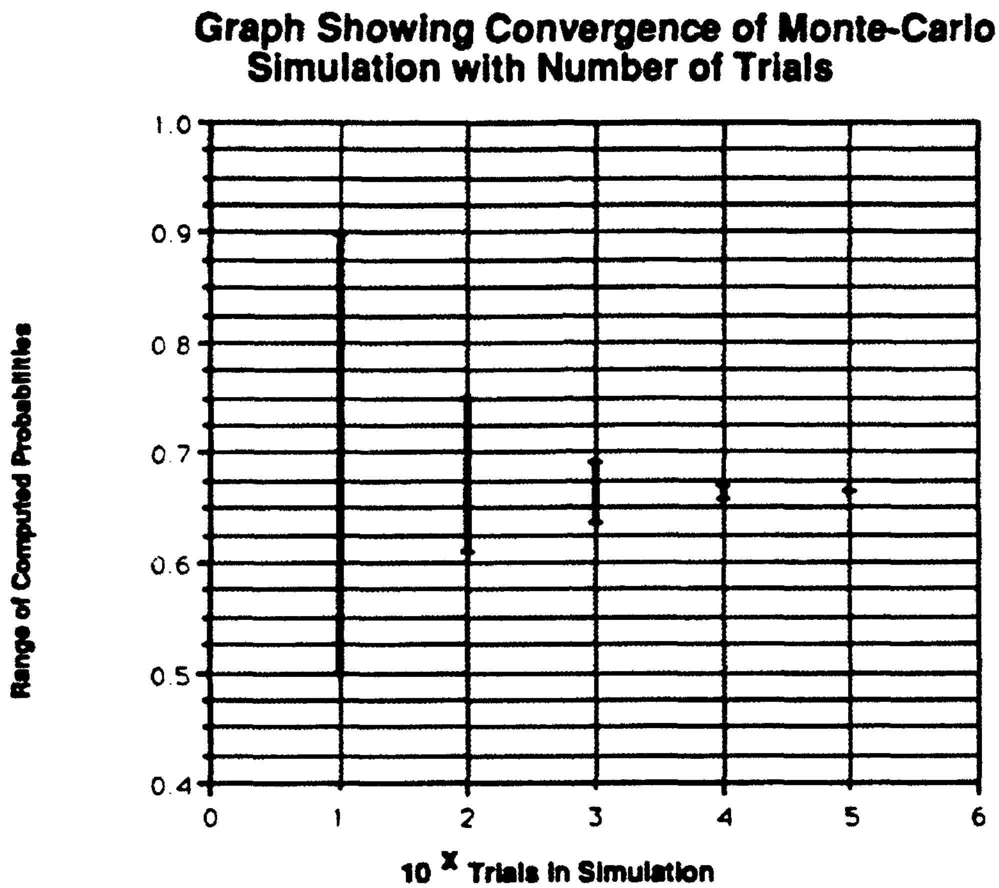

Graph Showing Convergence of Monte-Carlo Simulation with Number of Trials
1.0
0.9
0 8
0.7
0.6
0.5
0.4
0
1
2
3
4
5
6
Range of Computed Probabilities
10 X Trials in Simulation

Figure 15

6.0 Summary:

NetStat has been demonstrated to be a useful tool in assessing the reliability and connectivity of networks. It is able to solve, through the use of Monte-Carlo simulation, a wide array of problems which are otherwise intractable when approached in a closed-form manner. The problem space addressed by NetStat is currently of great importance as infrastructures and information systems become more complex and new ones are designed.

Problems such as those addressed by NetStat have been treated in current literature to the extent that closed form solutions could be derived in certain constrained problems. The metrics addressed by NetStat are generally accepted by the "networking" community as valid measures of reliability. It is in the area where closed form expressions cannot be derived that NetStat finds its utility. Additionally NetStat can be used to cross-validate closed form expressions where a higher level of confidence is required.

It is the goal of the application to be generally applicable. To this end, NetStat provides a number of network elements for topology construction so that real world situations can be modeled as accurately as possible. These elements include specialized nodes such as hubs and bypass switches as well as bidirectional and unidirectional links. Failure probabilities for individual elements can be specified as the problem dictates. Once it is understood how NetStat treats the various components in the simulation, specialized scenarios can be constructed.

NetStat also provides an easy to use graphic user interface. In this way visual feed back is available during problem setup. It is the aim of the application to be intuitive to operate so that more time can be spent on interpreting results than on problem set up. NetStat is implemented on the well known Macintosh platform increasing its ease of use and accessibility. Finally, ranges of output data can be generated in an easily graphable form so that a broad view of the problem can be mapped out.

References and Bibliography:

[1] Frank, H., et. al., Communication, Transmission, and Transportation Networks. Reading,MA: Addison-Wesley Co., 1971

[2] Harary, F., Graph Theory. Reading,MA: Addison-Wesley Co., Second Ed., 1971

[3] Deo, N., Graph Theory with Application to Engineering and Computer Science. , Englewood Cliffs , NJ: Prentice-Hall Inc., 1974

[4] Tanenbaum, A., Computer Networks. Englewood Cliffs , NJ: Prentice-Hall Inc., 1981

[5] Ed. Dallas, I.,et. al., Ring Technology Local Area Networks. Amsterdam,The Netherlands: Elsevier Science Pub. B.V., 1984

[6] "On the *Sample Sizes of Monte-Carlo Simulations - a Set of Useful Guidelines*", The MITRE Corp. , Bedford, MA.

[7] "Network Survivability Through Connectivity Optimization", The MITRE Corp. , Bedford, MA.

[8] "A Survivable Network for Base Recovery After Attack", The MITRE Corp. , Bedford, MA.

[9] Jeruchim, M., Techniques for Estimating the Bit Error Rate in the Simulation of Digital Communication Systems . IEEE J. of Selected Areas in Comm.,Jan 1984

[10] Cobb, R., Use Statistics to Test Communications Systems Efficiently . EDN,Jan 1987

[11] Lin, N.,et. al., Ring Network Reliability - The Probability that All Operative Nodes Can Communicate . IEEE Proc. 8th Symp. on Reliable Distributed Systems,Oct 1989

[12] Lin, N.,et. al., A Reliability Comparison of Single and Double Rings . IEEE Proc. of InfoCom,Jun 1990

[13] Boesch, F.,et. al., On Graphs of Invulnerable Communication Nets . IEEE Trans. on Circuit Theory,May 1970

[14] Ed. Boesch, F.,et. al., Networks, An International Journal. New York: Wiley Journals, Vol. 15, Num. 2, Summer 1985

[15] Ed. Boesch, F., Large Scale Networks, Theory and Design. New York: IEEE Press, 1976

APPENDIX A

NetStat, Version 1.2

<u>User's Manual</u>

G.S.Marzot

INTRODUCTION

The Network Survivable Topology Analytic Tool (NetStat) is a Macintosh application designed to aid a network architect or administrator in assessing the survivability/reliability of a given network topology. NetStat enables the user to graphically and interactively describe a network topology. The user is provided with several types of network elements(nodes,hubs,bypass-switches,unidirectional/bidirectional links) so that real-world topologies can be realized. After specifying destruction probabilities for each network element(individually or by type) the user can then run a Monte-Carlo simulation on the network to estimate certain connectivity metrics - the metrics available in this application are explained below. Tools are provided to edit, save and rearrange the topology so that a series of tradeoff scenarios may be investigated. In this way the user can allocate network resources in an intelligent way to maximize connectivity under a variety of conditions.

ABOUT BOX

Network Survivable Topology Analytic Tool (NetStat)
Version 1.2b by G. Marzot email:gmarzot@linus.mitre.org

This Freeware application is an extension of the survivability analysis described in the MITRE document, MTR-10665

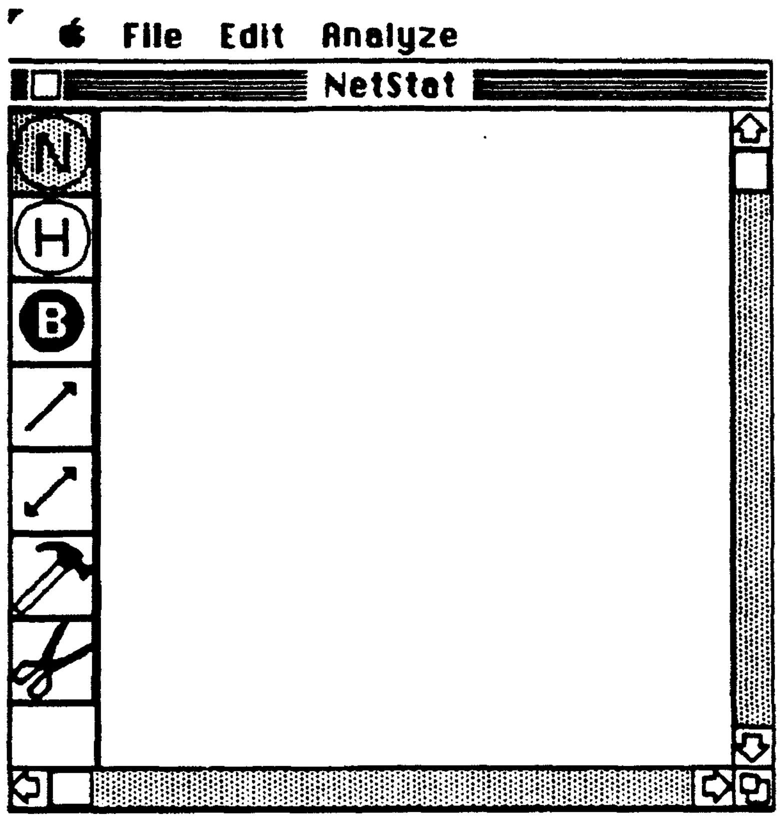
Aknowledgement to V.C.Georgopoulos and B.D.Metcalf

This application is also presented in partial fulfillment of my Tufts University MSEE project - Prof.Chang, Advisor

OK

USER INTERFACE

toolpalette:



The network architectures are constructed in the application's drawing pad in the main part of the application window. In the left hand side of the application window a toolpalette is provided to assist in this operation. Each icon in the palette, when selected, corresponds to a mode that determines what will be drawn(or erased) in the drawing pad. A tool is selected by clicking on its icon in the palette. The icon remains selected (greyed) until the task associated with it is performed once then the tool becomes unselected and the cursor returns to an arrow. A tool may be indefinitely selected (locked/black) by double-clicking in the desired icon. The user may now perform the selected task a number of times. The user may change the tool by clicking in another icon or return to the default arrow tool by clicking in the blank area at the bottom of the palette. The tasks performed when each tool is selected are listed:

Node Tool - Add node to architecture by clicking in drawing pad, cursor is a square

Hub Tool - Add hub to architecture by clicking in drawing pad, cursor is a square

Bypass Tool - Add a bypass switch to architecture by clicking in drawing pad,cursor is a square

Simplex Link Tool - Join any two nodes(nodes,hubs or bypasses) by clicking in the source node then in the destination node(order determines direction), the cursor is a line with one arrow

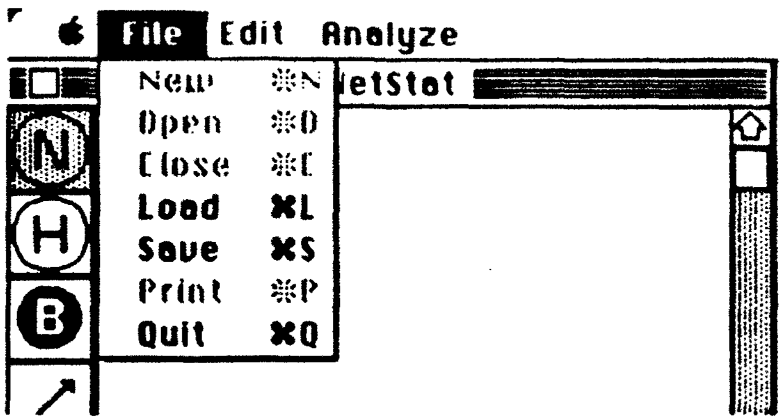
Duplex Link Tool - Join any two nodes by clicking in the source node then in the destination node(order does not matter), the cursor is a line with two arrows

Hammer Tool - Remove any node by clicking in it, all links incident on the node are also removed, cursor is a hammer

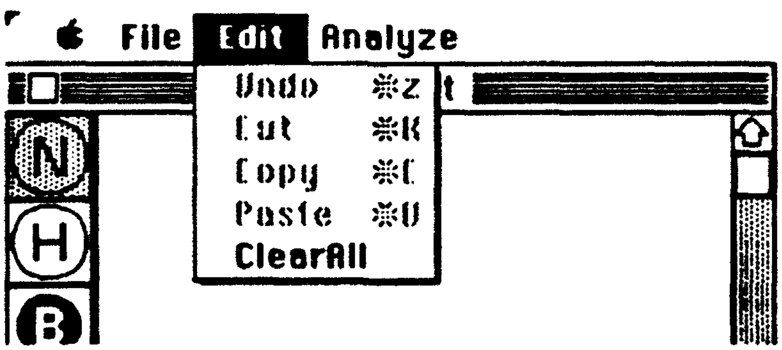
Scissor Tool - Remove a link by clicking first in one terminal node then in the other(order does not matter) , the most recently added link will be removed, cursor is a pair of scissors

Arrow Tool - Default tool, Inspect the state of any network element (node or link) by clicking in(on) it and set the failure probability provided that option has been checked in the Simulation Parameters dialog box(see below), cursor is an arrow

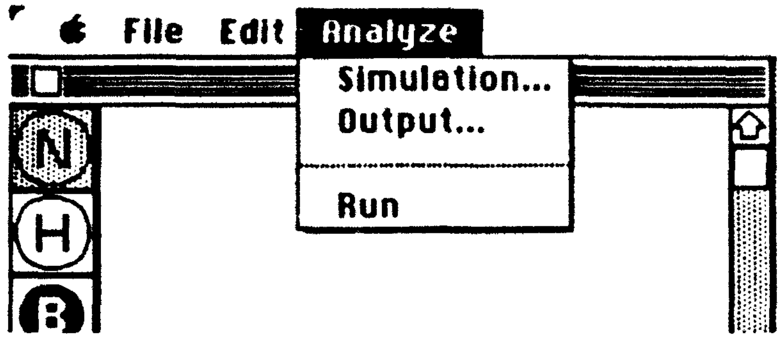
menus:



The **File** menu allows a preexistent architecture to be loaded from a file using the **Load** menu item. The architecture is usually stored in a file with the name "fname.arch". The **Save** menu item will allow a recently constructed topology to be saved to a file along with all present application settings. The **Quit** menu item quits the application. (note: clicking in the application close box also quits the application.) All other greyed items are unimplemented.

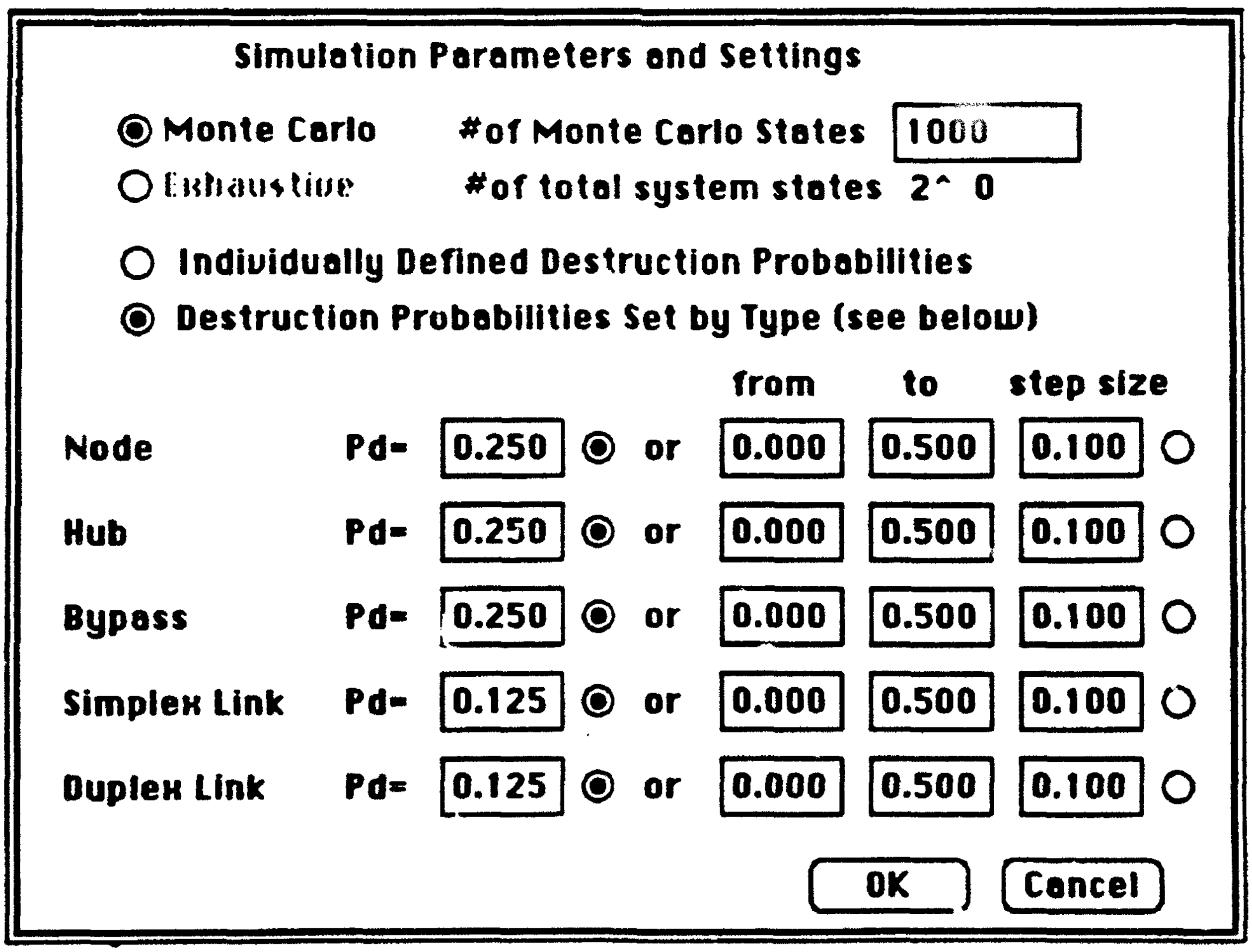


The **Edit** menu allows the user to remove all nodes and links in the drawing pad by selecting the **ClearAll** menu item. All other greyed items are unimplemented.

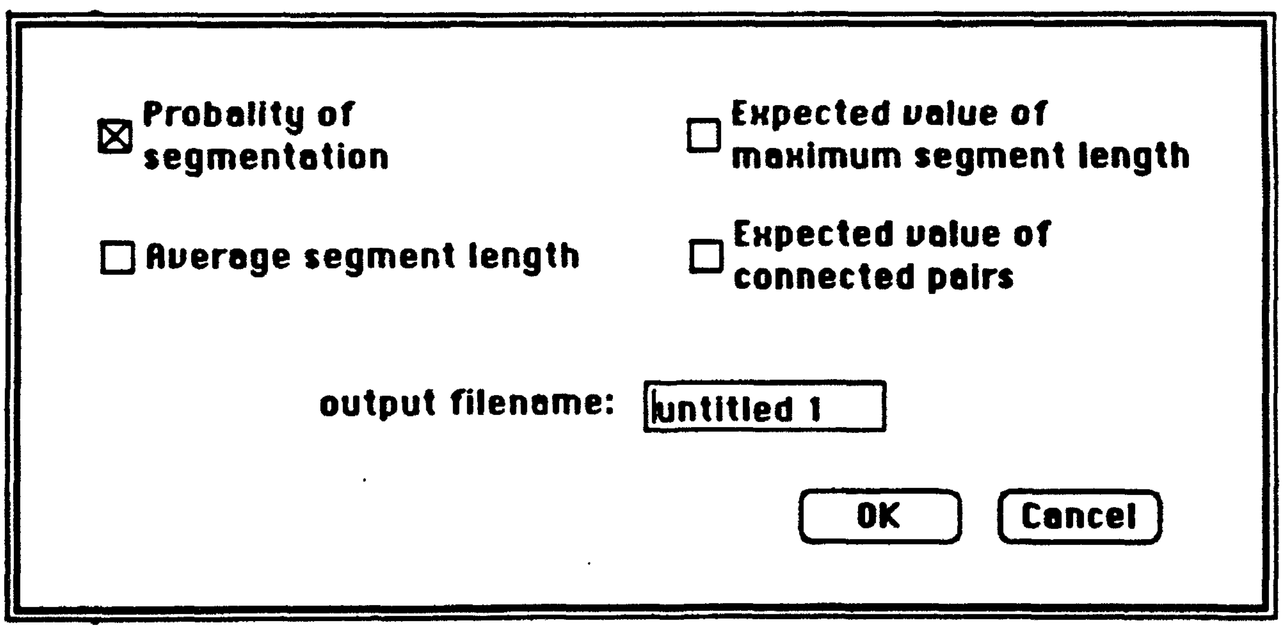


The **Analyze** menu allows the user to set parameters related to the simulation and the output format. By selecting the **Simulation...** menu item the Simulation Parameters and Settings dialog box is displayed(see below). By selecting the **Output...** menu item a dialog box displaying output specifications is displayed (see below). The **Run** menu item initiates a simulation in accordance with the present application settings.

dialogs:

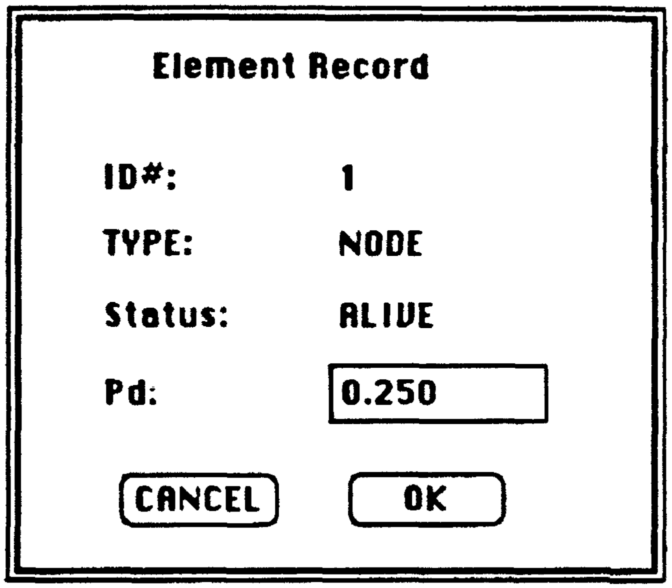


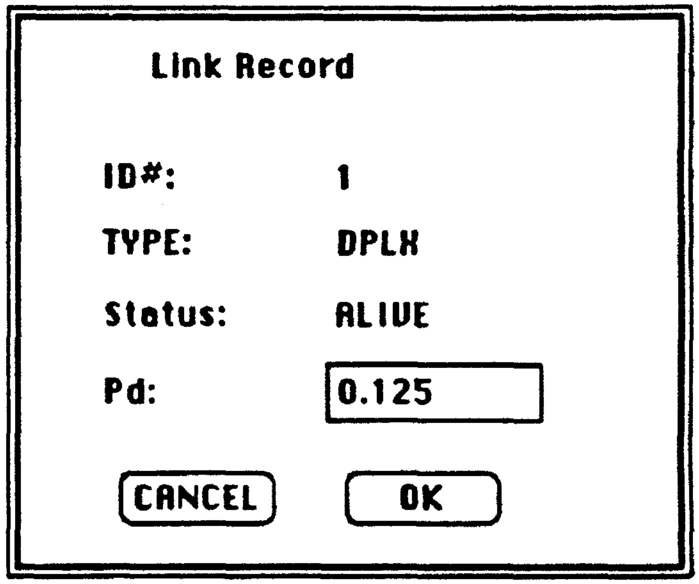
The Simulation Parameters and Settings dialog box allows the user to specify the number of Monte-Carlo trials that will be generated in the simulation. As a reference the total number of system states, based on a binary state for each network element, is shown in a static text field. The exhaustive simulation is unimplemented. This would generate every realizable state for the system and would be unrealistic for most networks. A radio button is provided to choose between individually definable failure probabilities for the network elements or failure probabilities which are set by element type (i.e., node, hub, simplex link, etc.) . When the individually settable option is selected each element can be assigned a different Pd (see ToolPalette for details). When the "by type" option is selected all elements of the given type will have the same Pd. When the destruction probabilities are set by type there is a further option to make them constant or generate data over a range of destruction probabilities. (note: the choice of a ranges produces nested loops and will greatly increase simulation time, Best to run once with constant probabilities and then determine how many iterations are reasonable)



The output settings dialog box determines which metrics will be generated and put out to a file when the **Run** menu item is selected. A check mark

next to the metric indicates that it will be calculated and dumped to the specified file in the **output filename** text field. A ***special feature*** is enabled when no metric is checked. The probability of segmentation will still be calculated when **Run** is selected but no file I/O will take place and the result will still be printed to the screen. The simulation will run up to ***twice as fast*** in this mode.





These dialog boxes are displayed when the user clicks in or on any network element(node or link respectively) while the cursor is the default arrow. The Pd field may be edited to a probability between 0.0 and 1.0 inclusive provided the "individual setting" option has been checked in the Simulation Parameters dialog box.

CONNECTIVITY METRICS

When the Monte Carlo simulation is run an ensemble of the network states are generated and the connectivity metrics are computed over that ensemble. That means, that for one Monte-Carlo trial each network element may operational or non-operational,based on its Pd, resulting in a new network which is a subset of the original one. This resultant network can be analyzed in terms of its connectivity metrics (segmentation, segment size, connected pairs, etc.) and the result can be

stored. This process is repeated n times,where n is the number of Monte-Carlo trials, and the results are averaged over n producing estimates of the metrics.

Probability of Segmentation - In graph theory jargon, this is the probability that a given graph will contain more than one component. Stated again, it is the probability that at least one surviving node will not have duplex connection with at least one other surviving node.

Average Segment Length - Average segment length (normalized to the undamaged segment length)

Expected Value of Connected Pairs - Connected pairs are defined as the number of pairs of surviving nodes that can communicate in a given graph. For each segment the number of connected pairs equals N choose 2, or $N*(N-1)/2$ where N is the number of nodes in that segment. (Normalized to undamaged number of connected pairs)

Expected Value of Max. Segment Length - In each Monte-Carlo trial the size of the maximum segment is recorded and averaged over the ensemble of states. This is useful for investigating need for resource replication in distributed processing applications. (Normalized to undamaged segment length or total number of nodes)

FILE I/O

Output over ranges of input parameters can be computed and dumped to a file which is readable by CricketGraph™. The file is in tab delimited ASCII form and can be read by most graphing and plotting software.

Architectures can be saved to a file (Filename.arch) and reloaded later.

GRAPHING RESULTS W/ CricketGraph™

This is accomplished by selecting both the output file and Cricket Graph and then double-clicking on Cricket Graph. You may also read in the output file from CricketGraph by selecting the show text file option from within CricketGraphs **Open...** menu item dialog box. Appropriate column labels will be displayed.

LIMITATIONS/BUGS

The application is limited to 256 nodes with 256 links per node.

There is a limit of 4 links between any two nodes.

It is important to note that a 12 node system with 12 links simulating 10,000 Monte-Carlo states on a Mac IIcx takes approximately 10-15 seconds and that run time increases with the number of states and the number of total elements. Some simulations can run prohibitively long. Start with a small number of trials.

The application is designed to run on a Macintosh equipped with an 881/882 FPU, it will crash if one is not present.

The application will crash if you try to load an improper file - this bug will be fixed

GLOSSARY

Pd - the probability that a given network element will fail.

Nodes - Nodes represent network components such as terminals, modems, communication equipment or any similar items where users might reside or locations where messages are relayed. The term node is sometimes used to mean hubs and bypass switches as well.

Hubs - Hubs are the center nodes for star networks. Hubs are very similar to Nodes. The only difference is a conceptual one. The separate representation allows the individual setting of the hubs Pd as in a hardened hub star network where the hub has a Pd=0 and the nodes may have a non-zero Pd.

BypassSwitches - Bypass switches are usually three terminal components which can sense the loss of one connection and switch to the other. This allows nodes to be remoted from a network so that their loss has less of an impact on its connectivity. Bypasses are not counted in segment length ,connected pairs, nor is a segment consisting solely of switches considered valid for the probability of segmentation. Nodes and Hubs are.

SimplexLinks - Simplex links are unidirectional communication links. This allows each path of a duplex link to be represented separately. Connection with simplex links is deemed valid only if a round trip path exists between the elements being considered.

Duplex Links -Duplex links provide bidirectional communication between the two nodes connected. Any two elements linked with an operational duplex link are considered connected.

APPENDIX B

NetStat, Version 1.2

Source Code

ConsVars Unit

```
unit ConsVars;
interface
  const
                                {low memory nasties}
    kSFSaveDisk = $214;         { Negative of current volume refnum [WORD] }
    kCurDirStore = $398;        { DirID of current directory [LONG]          }

    DEF_STATES = 1000;              {default values for Simulation dialog box}
    DEF_NODE_PD = 0.25;
    DEF_LINK_PD = 0.125;
    DEF_FRM_PD = 0;
    DEF_TO_PD = 0.5;
    DEF_STP_SZ = 0.1;

    BASE_RES_ID = 400;              {base resource ID for most res}

    NIL_POINTER = 0;                {Parameters for various tool box calls}
    MOVE_TO_FRONT = -1;
    REMOVE_ALL_EVENTS = 0;
    SUSP_RES_MESS = 1;
    RES_MASK = 1;
    NO_EVENT = 0;

    ADD_CHECK_MARK = TRUE;      {menu check parameters}
    REMOVE_CHECK_MARK = FALSE;

    DRAG_THRESHOLD = 10;        {window parameters}
    SBarWidth = 15;
    TOOL_SIZE = 32;
    PAD_LIMIT = 1024;

    MAX_NEG = -32768;           {integer range}
    MAX_POS = 32767 - 1;

    MIN_SLEEP = 0;                  {parameters for waitnextevent call/verify}
    NIL_MOUSE_REGION = 0;
    WNE_TRAP_NUM = $60;
    UNIMPL_TRAP_NUM = $9F;

    SIM_DLOG = BASE_RES_ID + 1; {dialog box res ID}
    OUT_DLOG = BASE_RES_ID + 2;
    ELEM_DLOG = BASE_RES_ID + 3;
    LINK_DLOG = BASE_RES_ID + 4;

    NEW_ITEM = 1;                   {file menu items}
    OPEN_ITEM = 2;
    CLOSE_ITEM = 3;
    LOAD_ITEM = 4;
    SAVE_ITEM = 5;
    PRINT_ITEM = 6;
    QUIT_ITEM = 7;

    UNDO_ITEM = 1;                  {edit menu items}
```

```
    CUT_ITEM = 2;
    COPY_ITEM = 3;
    PASTE_ITEM = 4;
    CLEAR_ITEM = 5;

    SIM_ITEM = 1;                    {analyze menu items}
    OUT_ITEM = 2;
    RUN_ITEM = 4;

    ABOUT_ITEM = 1;                  {apple menu item}

    APPLE_MENU_ID = BASE_RES_ID;  {menu res IDs}
    FILE_MENU_ID = BASE_RES_ID + 1;
    EDIT_MENU_ID = BASE_RES_ID + 2;
    ANAL_MENU_ID = BASE_RES_ID + 3;

    NODE_ICON = BASE_RES_ID;            {tool/element icon res IDs}
    HUB_ICON = BASE_RES_ID + 1;
    BYP_ICON = BASE_RES_ID + 2;
    SPLX_ICON = BASE_RES_ID + 3;
    DPLX_ICON = BASE_RES_ID + 4;
    CUTN_ICON = BASE_RES_ID + 5;
    CUTL_ICON = BASE_RES_ID + 6;
    NULL_ICON = BASE_RES_ID + 7;

    ABOUT_ALERT = BASE_RES_ID;          {alert res ID}

    ELEM_CURS = BASE_RES_ID;            {cursor res IDs}
    CUT_NODE_CURS = BASE_RES_ID + 1;
    ADD_SLNK_CURS = BASE_RES_ID + 2;
    ADD_DLNK_CURS = BASE_RES_ID + 3;
    CUT_LINK_CURS = BASE_RES_ID + 4;

    DI_TOP = $0050;                  {location for error alert for bad disk routine}
    DI_LEFT = $0070;

    MAX_ITEMS = 127;                    {maximum nodes+bypass+hubs/links from one node}

    ALINK = TRUE;                       {parameter for cutelem}
    NOT_ALINK = FALSE;

    PI = 3.141592654;                   {π}

  type
    PtrToLong = ^longint;
    PtrToWord = ^integer;

{node/bypass/hub variables for set operations and bookeeping}
    NodeIDType = 0..255;
    NodeSet = set of NodeIDType;
    SetArrayType = array[0..127] of NodeSet;
    SArrayPtr = ^SetArrayType;
```

```
{tool related types}
    ToolStateType = (off, on, locked);
    ComType = (AddNode, AddHub, AddByp, AddSplx, AddDplx, CutNode, CutLink, NullCom);
    LinkComs = set of AddSplx..CutLink;
    MapType = array[AddNode..NullCom] of Rect;

{network element types}
    ElemType = (Node, Hub, Bypass, Dplx, Splx);
    LinkElems = set of Dplx..Splx;

{Node like element record structure}

    LinkPtr = ^Link;

    ElementPtr = ^Element;
    NodeArray = array[0..127] of ElementPtr;
    LinkArray = array[0..127] of LinkPtr;
    Element = record
        ID: NodeIDType;
        Kind: ElemType;
        Pd: Real;
        Loc: Rect;
        Alive: Boolean;
        LList: LinkArray
      end;
    FElement = record
        Kind: ElemType;
        Pd: Real;
        Loc: Rect;
      end;

{link element record structure}
    Link = record
        Kind: ElemType;
        End1ID, End2ID: integer;
        End1, End2: ElementPtr;
        HookPt1, A1pt1, A2pt1, HookPt2, A1pt2, A2pt2, Apt1, Apt2: Point;
        Alive: Boolean;
        Pd: real
      end;
    FLink = record
        Kind: ElemType;
        End1ID, End2ID: integer;
        Pd: real
      end;

{Dialog element types and record}
    DlogItemType = (Npd, Hpd, Bpd, Spd, Dpd, Nfr, Nto, Nst, Hfr, Hto, Hst, Bfr, Bto, Bst, Sfr, Sto, Sst, Dfr,
        Dto,{}
      Dst, Mst, Tst, Mon, Exh, Nc, Hc, Bc, Sc, Dc, Nr, Hr, Br, Sr, Dr, Ind, Typ, Pseg, Avsl, Ecp, Emsl);
    DialogRec = record
        SimStrArr: array[Npd..Tst] of Str255;     {Npd=3,Sst=24}
        SimRadArr: array[Mon..Typ] of boolean;        {Mon=48,Dr=59,Ind=25,
```

```
        Typ=26,from/to/step=33-35}
       OutChkArr: array[Pseg..Emsl] of boolean;        {Pseg=5,Emsl=8}
       OutFileStr: Str255                              {  }
      end;

    TFilePtr = ^text;

    ArchRec = record
       NodeArr: array[0..127] of FElement;
       LinkArr: array[0..127] of FLink;
       NumNodes: longint;
       NumLinks: longint;
       DlogRec: DialogRec
      end;
    ArchFile = file of ArchRec;
    AFilePtr = ^ArchFile;

  var
    gLinkSet: LinkElems;               {set of link elements to destinguish from nodes}
    gLComSet: LinkComs;                {set of link related commands to destringuish from node coms}
    gTState: ToolStateType;        {present state of the tool panel}
    gPadWindow: WindowPtr;             {global window storage}
    gSimDlogPtr, gOutDlogPtr, gElemDlogPtr, gLinkDlogPtr: DialogPtr;
                                       {Dialog Pointers to bne loaded in initially and dereferenced
        later}
    gDlogRec: DialogRec;           {record of dlog box item states}
    gDone,                             {TRUE when time to leave app}
    gWNEImplemented,                   {TRUE when WaitNextEvent trap is implemented}
    gFirstClick,                       {TRUE for first clik in content }
    gInBackground: Boolean;        {TRUE when application is in background used for activate event}
    gTheEvent: EventRecord;            {the event}
    gAppleMenu, gAnalMenu: MenuHandle; {menuhandels}
    gDragRect: Rect;                   {window drag limits}
    gVScroll, gHScroll: ControlHandle;   {scroll bar handles}
    gNumSegs, gTotalSegs, gNumStates, gSegCount, gCurrentTime, gOldTime, gFirstID, gNumNodes,
       gNumLinks: longint;
    gFileName: Str255;
    gOrigin: Point;
    gPseg, gAvsl, gEcp, gEmsl, gPInch: extended;
    gUpdateRgn: RgnHandle;
    gMode: ComType;
    gTMap: MapType;
    gNodeArr: NodeArray;
    gNilLinkArr, gLinkArr: LinkArray;
    gMaxSegArr, gSegLnthArr: array[0..MAX_ITEMS] of longint;
    gWhenFirstClick: longint;
    gBypSet, gNodeSet: NodeSet;
    gWorld: SysEnvRec;
    gSFSaveDisk: PtrToWord;
    gCurDirStore: PtrToLong;
implementation
end.
```

Main

```
{$I+}
program Stat (input, output);
 uses
  ConsVars, Engine;

 procedure Grow (w: WindowPtr; p: Point);
 forward;

{** PathNameFromDirID
            **************************************************************}
{*}
{(*   Given a DirID and real vRefnum, this routine will create and return the}
{(*   full pathname that corresponds to it. It does this by calling PBGetCatInfo}
{(*   for the given directory, and finding out its name and the DirID of its}
{(*   parent. It the performs the same operation on the parent, sticking ITS}
{(*   name onto the beginning of the first directory. This whole process is}
{(*   carried out until we have processed the root directory (identified with}
{(*   a DirID of 2.}
{(*}

 function PathNameFromDirID (DirID: longint; vRefnum: integer): str255;

  var
   Block: CInfoPBRec;
   directoryName, FullPathName: str255;
   err: OSerr;
 begin
  FullPathName := '';
  with block do
   begin
    ioNamePtr := @directoryName;
    ioDrParID := DirId;
   end;

  repeat
   with block do
    begin
     ioVRefNum := vRefNum;
     ioFDirIndex := -1;
     ioDrDirID := block.ioDrParID;
    end;
   err := PBGetCatInfo(@Block, FALSE);


   directoryName := concat(directoryName, ':');
   fullPathName := concat(directoryName, fullPathName);

  until (block.ioDrDirID = 2);

  PathNameFromDirID := fullPathName;
 end;
{** PathNameFromWD
            **************************************************************}
```

```
{*}
{(*   Given an HFS working directory, this routine returns the full pathname}
{(*   that corresponds to it. It does this by calling PBGetWDInfo to get the}
{(*   VRefNum and DirID of the real directory. It then calls PathNameFromDirID,}
{(*   and returns its result.}
{(*}
{(*********************************************************************
     **********}

 function PathNameFromWD (vRefNum: longint): str255;

  var
   myBlock: WDPBRec;
   err:  OSerr;
 begin
  with myBlock do
   begin
    ioNamePtr := nil;
    ioVRefNum := vRefNum;
    ioWDIndex := 0;
    ioWDProcID := 0;
   end;

        { Change the Working Directory number in vRefnum into a real vRefnum }
        { and DirID. The real vRefnum is returned in ioVRefnum, and the real }
        { DirID is returned in ioWDDirID. }

  err := PBGetWDInfo(@myBlock, FALSE);

  with myBlock do
   PathNameFromWD := PathNameFromDirID(ioWDDirID, ioWDVRefnum)
 end;



{/****************     Binomial     ****************/}
 function Binomial (num: integer): integer;
  var
   i, p: integer;
 begin
  p := 1;
  if num > 1 then
   p := (((num - 1) * num) div 2)
  else
   p := 0;
  Binomial := p
 end;

{/************     DoubleClick     ********************/}
 function DoubleClick: boolean;
 begin
  if TickCount > (gWhenFirstClick + GetDblTime) then
```

```
    begin
     gWhenFirstClick := TickCount;
     DoubleClick := FALSE
    end
   else
    begin
     DoubleClick := TRUE;
     gWhenFirstClick := 0
    end
 end;


{/***************RNumToString***************/}
 procedure RNumToString (num: real; var theString: Str255);
  var
   myString1, myString2, myString3: Str255;
   i: integer;
 begin
  NumToString(trunc(num), myString3);
  num := Abs(num - trunc(num));
  i := round(num * 1000);
  myString2 := '.';
  NumToString(i, myString1);
  if ((i < 100) and (i >= 10)) then
   myString1 := concat('0', myString1)
  else if i < 10 then
   myString1 := concat('00', myString1);
  theString := concat(myString3, myString2, myString1)
 end;


{/*******************      StringToRNum     ***************/}
 procedure StringToRnum (theString: Str255; var num: real);
  var
   myString1, myString2: Str255;
   i, j, k: integer;
   n: longint;
 begin
  i := pos('.', theString);
  if i = 0 then
   begin
    StringToNum(theString, n);
    num := n;
    Exit(StringToRNum)
   end;

  k := pos('-', theString);
  if k = 0 then
   begin
    myString1 := copy(theString, 1, i - 1);
    StringToNum(myString1, n);
    j := 1
   end
```

```
    else
     begin
      myString1 := copy(theString, k + 1, i - 1 - k);
      StringToNum(myString1, n);
      j := -1
     end;

   num := n;
   myString1 := copy(theString, i + 1, 1);
   StringToNum(myString1, n);
   num := num + (n / 10);
   myString1 := copy(theString, i + 2, 1);
   StringToNum(myString1, n);
   num := num + (n / 100);
   myString1 := copy(theString, i + 3, 1);
   StringToNum(myString1, n);
   num := num + (n / 1000);
   num := num * j;
  end;
{/**************     IsDAWindow     *****************/}
 function IsDAWindow (w: WindowPtr): Boolean;
 begin
  if w = nil then
   IsDAWindow := FALSE
  else
   IsDAWindow := (WindowPeek(w)^.windowkind < 0)
 end;

{/****************     IsAppWindow     ******************/}
 function IsAppWindow (w: WindowPtr): Boolean;
 begin
  if w = nil then
   IsAppWindow := FALSE
  else
   IsAppWindow := (WindowPeek(w)^.windowkind = userkind)
 end;

{/**********     SetScreen******/}
 procedure SetScreen;
  var
   theRect: Rect;
 begin
  theRect := gPadWindow^.portRect;
  theRect.right := theRect.right - SBarWidth;
  theRect.bottom := theRect.bottom - SBarWidth;
  theRect.left := theRect.left + TOOL_SIZE + 2;
  OffsetRect(theRect, gOrigin.h, gOrigin.v);
  ClipRect(theRect);
  SetOrigin(gOrigin.h, gOrigin.v)
 end;

{/*********     ResetScreen*********/}
 procedure ResetScreen;
```

```
 begin
  SetOrigin(0, 0);
  ClipRect(screenBits.bounds)
 end;

{/****************** DrawArrows ********************/}
 procedure DrawArrows (theLink: LinkPtr);
  var
   rise, run: integer;
   pt1, pt2: Point;
   sp, ep1, ep2: point;
 begin
  with theLink^ do
   begin

    PenSize(2, 2);
    MoveTo(A1pt1.h, A1pt1.v);
    LineTo(Apt1.h, Apt1.v);
    MoveTo(A2pt1.h, A2pt1.v);
    LineTo(Apt1.h, Apt1.v);
    if kind = Dplx then
     begin
      MoveTo(A1pt2.h, A1pt2.v);
      LineTo(Apt2.h, Apt2.v);
      MoveTo(A2pt2.h, A2pt2.v);
      LineTo(Apt2.h, Apt2.v);
     end
   end;
  PenSize(1, 1)
 end;

{/ * * * * * * * * * * * * * * * * * * * * * * * DrawCont * * * * * * * * * * * * * * * * * * * /}

 procedure DrawCont;
  var
   theRect: Rect;
   myTimeString: Str255;
   ih: Handle;
   ph: PicHandle;
   i, j: integer;
 begin
  for i := 1 to gNumNodes do
   begin
    j := 1;
    ih := GetIcon(NODE_ICON + ord(gNodeArr[i]^.kind) - ord(Node));
    PlotIcon(gNodeArr[i]^.Loc, ih);
    while gNodeArr[i]^.LList[j] <> nil do
     begin
      MoveTo(gNodeArr[i]^.LList[j]^.HookPt1.h, gNodeArr[i]^.LList[j]^.HookPt1.v);
      LineTo(gNodeArr[i]^.LList[j]^.HookPt2.h, gNodeArr[i]^.LList[j]^.HookPt2.v);
      DrawArrows(gNodeArr[i]^.LList[j]);
      j := j + 1
     end
```

```
   end
 end;


{/************   GrayIcon   ************/}
 procedure GrayIcon (com: ComType);
  var
   ih: Handle;
 begin
  ih := GetIcon(NODE_ICON + ord(com) - ord(AddNode));
  PlotIcon(gTMap[com], ih);
  PenMode(PatOr);
  PenPat(ltGray);
  PaintRect(gTMap[com]);
  PenPat(black);
  PenMode(patCopy)
 end;


{/ * * * * * * * * * * * * * * * * * * DrawTools * * * * * * * * * * * * * * * * * /}

 procedure DrawTools;
  var
   ih: Handle;
   tRect: Rect;
   com: ComType;
   prevBottom: integer;
 begin
  PenSize(1, 1);
  prevBottom := gPadWindow^.portRect.top;
  for com := AddNode to CutLink do
   begin
    gTMap[com] := gPadWindow^.portRect;
    gTMap[com].top := prevBottom;
    gTMap[com].right := gTMap[com].left + TOOL_SIZE;
    gTMap[com].bottom := gTMap[com].top + TOOL_SIZE;
    prevBottom := gTMap[com].bottom;
    ih := GetIcon(NODE_ICON + ord(com) - ord(AddNode));
    PlotIcon(gTMap[com], ih);
    FrameRect(gTMap[com])
   end;
  SetRect(gTMap[NullCom], 0, 0, 0, 0);
  MoveTo(gTMap[CutLink].left, gTMap[CutLink].bottom);
  LineTo(gTMap[CutLink].right + 1, gTMap[CutLink].bottom);
  if gMode <> NullCom then
   case gTState of
    on:
     begin
      GrayIcon(gMode)
     end;
    locked:
     begin
      InvertRect(gTMap[gMode]);
```

```
      end;
     off:
    end;
   PenSize(2, 1);
   tRect := gPadWindow^.portRect;
   tRect.right := tRect.left + TOOL_SIZE;
   MoveTo(tRect.right, tRect.top);
   LineTo(tRect.right, tRect.bottom - SBarWidth);
   PenSize(1, 1)
  end;

{    /* * * * * * * * * * * * * * * * * * * * * * * * DrawWindow * * * * * * * * * * * * * * * * */}

 procedure DrawWindow (theWindow: WindowPtr);
  var
   theRect: Rect;
   myTimeString: Str255;
 begin
  SetScreen;
  DrawCont;
  ResetScreen;
  DrawTools
 end;

{/* * * * * * * * * * * * UpdateWindow * * * * * * * * * * * * * * * * * * * * * * */}

 procedure UpdateWindow (theWindow: WindowPtr);
  var
   savePort: GrafPtr;
 begin
  GetPort(savePort);
  SetPort(theWindow);
  BeginUpdate(theWindow);
  if not EmptyRgn(theWindow^.visRgn) then
   begin
    EraseRect(theWindow^.portRect);
    DrawWindow(theWindow);
    DrawControls(theWindow);
    DrawGrowIcon(theWindow)
   end;
  EndUpdate(theWindow);
  SetPort(savePort)
 end;


{    /* * * * * * * * * * * * * * * * * * Grow * * * * * * * * * * * * * * * * * * * * * * */}

 procedure Grow (w: WindowPtr; p: Point);
  var
   savePort: GrafPtr;
   theResult: longint;
   oScroll: integer;
```

```
   r, oView, viewRect: Rect;
 begin
  GetPort(savePort);
  SetPort(w);
  SetRect(r, TOOL_SIZE + 18, 7 * TOOL_SIZE + 18, screenBits.bounds.right, screenBits.bounds.bottom);
  theResult := GrowWindow(w, p, r);
  if (theResult <> 0) then
   begin
    viewRect := w^.portRect;
    InvalRect(gVScroll^^.contrlRect);
    InvalRect(gHScroll^^.contrlRect);
    EraseRect(gVScroll^^.contrlRect);
    EraseRect(gHScroll^^.contrlRect);
    viewRect.left := viewRect.right - SBarWidth;
    viewRect.top := viewRect.bottom - SBarWidth;
    InvalRect(viewRect);
    EraseRect(viewRect);
    SizeWindow(w, LoWord(theResult), HiWord(theResult), TRUE);
    HidePen;
    MoveControl(gVScroll, w^.portRect.right - SBarWidth, w^.portRect.tcp - 1);
    SizeControl(gVScroll, SBarWidth + 1, w^.portRect.bottom - w^.portRect.top - (SBarWidth - 2));
    MoveControl(gHScroll, w^.portRect.left - 1, w^.portRect.bottom - SBarWidth);
    SizeControl(gHScroll, w^.portRect.right - w^.portRect.left - (SBarWidth - 2), SBarWidth + 1);
    ShowPen;
    UpdateWindow(w);
    SetPort(savePort)
   end
 end;


{    /* * * * * * * * * * * * * * * * * * * * * * * HandleNull * * * * * * * * * * * * * * * * * * /}

{/******************          SaveSettings       ****************************/}
 procedure SaveSettings (theDlog: DialogPtr);
  var
   itemType: integer;
   i: DlogItemType;
   itemHandle: Handle;
   itemRect: rect;
 begin
  with gDlogRec do
   begin
    if theDlog = gSimDlogPtr then
     begin
      for i := Npd to Mst do
       begin
        GetDItem(gSimDlogPtr, (ord(i) - ord(Npd) + 3), itemType, itemHandle, itemRect);
        GetIText(itemHandle, SimStrArr[i]);
       end;
      for i := Mon to Typ do
       begin
        If i < Ind then
         begin
```

```
            GetDItem(gSimDlogPtr, (ord(i) - ord(Mon) + 48), itemType, itemHandle, itemRect);
            SimRadArr[i] := Boolean(GetCtlValue(ControlHandle(itemHandle)))
          end
        else
          begin
            GetDItem(gSimDlogPtr, (ord(i) - ord(Ind) + 25), itemType, itemHandle, itemRect);
            SimRadArr[i] := Boolean(GetCtlValue(ControlHandle(itemHandle)))
          end;
        end
      end
    else
      begin
        for i := Pseg to Emsl do
          begin
            GetDItem(gOutDlogPtr, (ord(i) - ord(Pseg) + 5), itemType, itemHandle, itemRect);
            OutChkArr[i] := Boolean(GetCtlValue(ControlHandle(itemHandle)))
          end;
        GetDItem(gOutDlogPtr, 3, itemType, itemHandle, itemRect);
        GetIText(itemHandle, OutFileStr)
      end
    end
end;

{/*****************    Restore    Settings    ************************/}
procedure RestoreSettings (theDlog: DialogPtr);
  var
    i: DlogItemType;
    itemType: integer;
    itemHandle: Handle;
    itemRect: rect;
begin
  with gDlogRec do
    begin
      BringToFront(theDlog);
      if theDlog = gSimDlogPtr then
        begin
          GetDItem(gSimDlogPtr, 25, itemType, itemHandle, itemRect);
          SetCtlValue(ControlHandle(itemHandle), Integer(SimRadArr[Ind]));
          GetDItem(gSimDlogPtr, 26, itemType, itemHandle, itemRect);
          SetCtlValue(ControlHandle(itemHandle), Integer(SimRadArr[Typ]));
          for i := Npd to Mst do
            begin
              GetDItem(gSimDlogPtr, (ord(i) - ord(Npd) + 3), itemType, itemHandle, itemRect);
              SetIText(itemHandle, SimStrArr[i]);

            end;
          for i := Mon to Dr do
            begin
              GetDItem(gSimDlogPtr, (ord(i) - ord(Mon) + 48), itemType, itemHandle, itemRect);
              SetCtlValue(ControlHandle(itemHandle), Integer(SimRadArr[i]));
            end;

        end
```

```
    else
     begin
      for i := Pseg to Emsl do
       begin
        GetDItem(gOutDlogPtr, (ord(i) - ord(Pseg) + 5), itemType, itemHandle, itemRect);
        SetCtlValue(ControlHandle(itemHandle), Integer(OutChkArr[i]));
       end;
      GetDItem(gOutDlogPtr, 3, itemType, itemHandle, itemRect);
      SetIText(itemHandle, OutFileStr)
     end
   end
 end;

{/ * * * * * * * * * * * * HandleAppleChoice * * * * * * * * * * * * * * * * * * * * /}

 procedure HandleAppleChoice (theItem: integer);
  var
   accName: Str255;
   n, accNumber: integer;
   itenNumber: Byte;
   AboutDialog: DialogPtr;
 begin
  case (theItem) of
   ABOUT_ITEM:
    n := NoteAlert(ABOUT_ALERT, nil);
   otherwise
    begin
     GetItem(gAppleMenu, theItem, accName);
     accNumber := OpenDeskAcc(accName)
    end
  end
 end;

{/***********     HiliTool     ************/}
 procedure HiliTool (com: ComType);
  var
   theRect: Rect;
   ih: Handle;
   dbl: boolean;
 begin
  dbl := DoubleClick;
  if (gMode = com) then
   begin
    if not dbl then
     begin
      if gTState = on then
       begin
        gMode := NullCom;
        gTState := off;
        gFirstClick := TRUE;
        gFirstID := 0;
        ih := GetIcon(NODE_ICON + ord(com) - ord(AddNode));
        PlotIcon(gTMap[com], ih)
```

```
        end
       else
        begin
         if com <> NullCom then
          begin
           gTState := on;
           GrayIcon(com)
          end
        end
      end
     else
      begin
       if com <> NullCom then
        begin
         gTState := locked;
         ih := GetIcon(NODE_ICON + ord(com) - ord(AddNode));
         PlotIcon(gTMap[com], ih);
         InvertRect(gTMap[com])
        end
      end
    end
   else
    begin
     if com <> NullCom then
      begin
       gTState := on;
       ih := GetIcon(NODE_ICON + ord(gMode) - ord(AddNode));
       PlotIcon(gTMap[gMode], ih);
       gMode := com;
       GrayIcon(com)
      end
     else
      begin
       ih := GetIcon(NODE_ICON + ord(gMode) - ord(AddNode));
       PlotIcon(gTMap[gMode], ih);
       gMode := com;
       gTState := off
      end
    end
 end;

{/***********     FindElem     ***************/}
 function FindElem (pt: point): integer;
  var
   p: point;
   done: boolean;
   Elem: integer;
 begin
  p.h := pt.h + gOrigin.h;
  p.v := pt.v + gOrigin.v;
  Elem := 0;
  done := FALSE;
  if gNumNodes > 0 then
```

```
    repeat
     Elem := Elem + 1;
     done := PtInRect(p, gNodeArr[Elem]^.Loc);
    until (done or (Elem = gNumNodes));
   if not done then
    Elem := 0;
   FindElem := Elem
  end;


{/***********     GetLinkNum     **************/}
 function GetLinkNum (pt: point): integer;
  var
   p: point;
   horiz, vert, done: boolean;

   rise1, rise2, run1, run2, link: integer;
 begin
  p.h := pt.h + gOrigin.h;
  p.v := pt.v + gOrigin.v;
  link := 0;
  done := FALSE;
  if gNumLinks > 0 then
   repeat
    link := link + 1;
    with gLinkArr[link]^ do
     begin
      vert := (HookPt1.h = HookPt2.h);
      horiz := (HookPt1.v = HookPt2.v);
      if ((p.h <= HookPt1.h) and (p.h >= HookPt2.h)) or ((p.h <= HookPt2.h) and (p.h >= HookPt1.h)) then
       if ((p.v <= HookPt1.v) and (p.v >= HookPt2.v)) or ((p.v <= HookPt2.v) and (p.v >= HookPt1.v))
     then
        begin
         run1 := HookPt1.h - HookPt2.h;
         rise1 := HookPt1.v - HookPt2.v;
         run2 := HookPt1.h - p.h;
         rise2 := HookPt1.v - p.v;
         if (horiz and (abs(p.v - HookPt1.v) = 0)) then
          done := TRUE
         else if (vert and (abs(p.h - HookPt1.h) = 0)) then
          done := TRUE
         else if (abs(round((rise1 / run1) * run2) - rise2) <= 1) then
          done := TRUE
         else if (abs(round((run1 / rise1) * rise2) - run2) <= 1) then
          done := TRUE;

        end;



     end;
   until (done or (link = gNumLinks));
  if not done then
```

```
    link := 0;
   GetLinkNum := link
  end;

{/**************     PopElemDLOG     ****************/}
 procedure PopElemDLOG (theElem: integer);
  var
   dun: boolean;
   IDStr: Str255;
   TypeStr: Str255;
   StatusStr: Str255;
   PdStr: Str255;
   theNewPd: real;
   itemType: integer;
   itemHandle: Handle;
   itemRect: rect;
   Item: integer;
   result: integer;
 begin
  BringToFront(gElemDlogPtr);

  NumToString(theElem, IDStr);
  GetDItem(gElemDlogPtr, 4, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, IDStr);

  case gNodeArr[theElem]^.Kind of
   Hub:
    TypeStr := 'HUB';
   Node:
    TypeStr := 'NODE';
   Bypass:
    TypeStr := 'BYPASS';
   otherwise
  end;
  GetDItem(gElemDlogPtr, 6, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, TypeStr);

  if gNodeArr[theElem]^.Alive then
   StatusStr := 'ALIVE'
  else
   StatusStr := 'DEAD';
  GetDItem(gElemDlogPtr, 8, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, StatusStr);

  RNumToString(gNodeArr[theElem]^.Pd, PdStr);
  GetDItem(gElemDlogPtr, 10, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, PdStr);

  ShowWindow(gElemDlogPtr);
  while not dun do
   begin
    ModalDialog(nil, Item);
    case Item of
```

```
      1:
       begin
        GetDItem(gElemDlogPtr, 10, ItemType, ItemHandle, ItemRect);
        GetIText(itemHandle, PdStr);
        StringToRNum(PdStr, theNewPd);
        If (theNewPd <= 1.0) and (theNewPd >= 0) then
         begin
          If (theNewPd <> gNodeArr[theElem]^.Pd) then
           begin
            If (gDlogRec.SimRadArr[Ind]) then
             begin
              gNodeArr[theElem]^.Pd := theNewPd;
              Hidewindow(gElemDlogPtr);
              dun := TRUE;
             end
            else
             result := NoteAlert(402, nil);
           end
          else
           begin
            Hidewindow(gElemDlogPtr);
            dun := TRUE;
           end;
         end
        else
         begin
          RNumToString(gNodeArr[theElem]^.Pd, PdStr);
          GetDItem(gElemDlogPtr, 10, ItemType, ItemHandle, ItemRect);
          SetIText(itemHandle, PdStr);
          result := NoteAlert(401, nil);
         end;
       end;
      2:
       begin
        HideWindow(gElemDlogPtr);
        dun := TRUE
       end;
     end;
    end;
  end;

{/***************      PopLinkDLOG      *****************/}
 procedure PopLinkDLOG (theLink: integer);
  var
   dun: boolean;
   IDStr: Str255;
   TypeStr: Str255;
   StatusStr: Str255;
   PdStr: Str255;
   theNewPd: real;
   ItemType: integer;
   ItemHandle: Handle;
   ItemRect: rect;
```

```
   Item: integer;
   result: integer;
 begin
  BringToFront(gLinkDlogPtr);

  NumToString(theLink, IDStr);
  GetDItem(gLinkDlogPtr, 4, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, IDStr);

  case gLinkArr[theLink]^.Kind of
   Dplx:
    TypeStr := 'DPLX';
   Splx:
    TypeStr := 'SPLX';
   otherwise
  end;
  GetDItem(gLinkDlogPtr, 6, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, TypeStr);

  if gLinkArr[theLink]^.Alive then
   StatusStr := 'ALIVE'
  else
   StatusStr := 'DEAD';
  GetDItem(gLinkDlogPtr, 8, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, StatusStr);

  RNumToString(gLinkArr[theLink]^.Pd, PdStr);
  GetDItem(gLinkDlogPtr, 10, ItemType, ItemHandle, ItemRect);
  SetIText(itemHandle, PdStr);

  ShowWindow(gLinkDlogPtr);
  while not dun do
   begin
    ModalDialog(nil, Item);
    case Item of
     1:
      begin
       GetDItem(gLinkDlogPtr, 10, ItemType, ItemHandle, ItemRect);
       GetIText(itemHandle, PdStr);
       StringToRNum(PdStr, theNewPd);
       if (theNewPd <= 1.0) and (theNewPd >= 0) then
        begin
         if (theNewPd <> gLinkArr[theLink]^.Pd) then
          begin
           if (gDlogRec.SimRadArr[Ind]) then
            begin
             gLinkArr[theLink]^.Pd := theNewPd;
             Hidewindow(gLinkDlogPtr);
             dun := TRUE;
            end
           else
            result := NoteAlert(402, nil);
          end
```

```
          else
           begin
            Hidewindow(gLinkDlogPtr);
            dun := TRUE;
           end;
         end
        else
         begin
          RNumToString(gLinkArr[theLink]^.Pd, PdStr);
          GetDItem(gLinkDlogPtr, 10, ItemType, ItemHandle, ItemRect);
          SetIText(itemHandle, PdStr);
          result := NoteAlert(401, nil);
         end;
       end;
      2:
       begin
        HideWindow(gLinkDlogPtr);
        dun := TRUE
       end;
     end;
    end;
 end;


{/****************     NumLinks     ****************/}
 function NumLinks (ind1, ind2: integer): integer;

  var
   i, j, k: integer;
 begin
  j := 1;
  k := 0;
  while gNodeArr[ind1]^.LList[j] <> nil do
   begin
    if gNodeArr[ind1]^.LList[j]^.End2 = gNodeArr[ind2] then
     k := k + 1;
    j := j + 1
   end;
  j := 1;
  while gNodeArr[ind2]^.LList[j] <> nil do
   begin
    if gNodeArr[ind2]^.LList[j]^.End2 = gNodeArr[ind1] then
     k := k + 1;
    j := j + 1
   end;
  NumLinks := k
 end;

{/**************     AssignHooks     ***************/}
 procedure AssignHooks (ID1, ID2: integer; var q1, h1, q2, h2: integer);
  var
   rect1, rect2: Rect;
   rise, run: Real;
```

```
    linkNum, slope: integer;
  begin
    rect1 := gNodeArr[ID1]^.Loc;
    rect2 := gNodeArr[ID2]^.Loc;
    rise := rect2.top - rect1.top;
    run := rect2.left - rect1.left;
    if abs(run) > abs(rise) then
      begin
        if run > 0 then
          begin
            q1 := 1;
            q2 := 2
          end
        else
          begin
            q1 := 2;
            q2 := 1
          end
      end
    else
      begin
        if rise > 0 then
          begin
            q1 := 4;
            q2 := 3
          end
        else
          begin
            q1 := 3;
            q2 := 4
          end
      end;
    h1 := NumLinks(ID1, ID2) + 1;
    h2 := h1;
    if h1 > 4 then
      q1 := 0

  end;

{/*****************     GetHookPt     ****************/}
  function HookPt (tRect: Rect; q, h: integer): Point;
    var
      p: Point;
      mult: integer;
  begin
    if odd(h) then
      mult := -1
    else
      mult := 1;
    case q of
      1:
        begin
          p.h := tRect.right - 1;
```

```
      p.v := tRect.top + (mult * (h div 2) + 1) * 5
     end;
    2:
     begin
      p.h := tRect.left;
      p.v := tRect.top + (mult * (h div 2) + 1) * 5
     end;
    3:
     begin
      p.v := tRect.top;
      p.h := tRect.left + (mult * (h div 2) + 1) * 5
     end;
    4:
     begin
      p.v := tRect.bottom - 1;
      p.h := tRect.left + (mult * (h div 2) + 1) * 5
     end;
    otherwise
   end;
   HookPt := p
  end;

{/****************           GetAPoints       *****************/}
 procedure GetAPoints (pt1, pt2: Point; var e1, e2, sp: Point);
  var
   rise, run, slope, theta, deltas, deltac, sx, sy, ex1, ey1, ex2, ey2: real;
 begin
  run := pt2.h - pt1.h;
  rise := pt2.v - pt1.v;
  if run <> 0 then
   begin
    slope := rise / run;
    theta := -arctan(slope)
   end
  else if rise < 0 then
   theta := Pi / 2
  else
   theta := 3 * Pi / 2;

  sx := pt1.h + 2 * run / 3;
  sp.h := round(sx);
  sy := pt1.v + 2 * rise / 3;
  sp.v := round(sy);
  deltac := 3.8 * cos(Pi / 4.7 - theta);
  deltas := 3.8 * sin(Pi / 4.7 - theta);
  if run >= 0 then
   begin
    ex1 := sx - deltac;
    ey1 := sy - deltas;
    ex2 := sx - deltas;
    ey2 := sy + deltac
   end
  else
```

```
    begin
      ex1 := sx + deltac;
      ey1 := sy + deltas;
      ex2 := sx + deltas;
      ey2 := sy - deltac
    end;
   e1.h := round(ex1);
   e1.v := round(ey1);
   e2.h := round(ex2);
   e2.v := round(ey2);
  end;


{/************     AddElem     *********/}
 procedure AddElem (tkind: ElemType; thePoint: Point);
  var
   theElement: ElementPtr;
   theLElement: LinkPtr;
   theRect: rect;
   ph: PicHandle;
   ih: Handle;
   erro: boolean;
   result, i, j, id, Q1, H1, Q2, H2: integer;
   pt1, pt2: Point;
 begin
  i := 0;
  j := 0;
  erro := FALSE;
  if tkind in gLinkSet then
   begin
    if gFirstClick then
     begin
      gFirstID := FindElem(thePoint);
      if gFirstID <> 0 then
       gFirstClick := False
     end
    else
     begin
      Q1 := 0;
      id := FindElem(thePoint);
      if ((id <> 0) and (id <> gFirstID)) then
       begin
        gFirstClick := TRUE;
        New(theLElement);
        with theLElement^ do
         begin
          kind := tkind;
          Alive := TRUE;
          End1ID := gFirstID;
          End2ID := id;
          End1 := gNodeArr[gFirstID];
          End2 := gNodeArr[id]
         end;
```

```
          repeat
            i := i + 1
          until (gNodeArr[gFirstID]^.LList[i] = nil) or (i = MAX_ITEMS);
          if i = MAX_ITEMS then
            erro := TRUE;
          if tkind = Splx then
            StringToRNum(gDlogRec.SimStrArr[Spd], theLElement^.Pd)
          else
            StringToRNum(gDlogRec.SimStrArr[Dpd], theLElement^.Pd);
          repeat
            j := j + 1
          until (gNodeArr[id]^.LList[j] = nil) or (j = MAX_ITEMS);
          if j >= MAX_ITEMS then
            erro := TRUE;
          AssignHooks(gFirstID, id, Q1, H1, Q2, H2)
        end;
      if Q1 = 0 then
        erro := TRUE;
      if not erro then
        begin
          with theLElement^ do
            begin
              HookPt1 := HookPt(gNodeArr[gFirstID]^.Loc, Q1, H1);
              HookPt2 := HookPt(gNodeArr[id]^.Loc, Q2, H2);
              GetAPoints(HookPt1, HookPt2, A1pt1, A2pt1, Apt1);
              GetAPoints(HookPt2, HookPt1, A1pt2, A2pt2, Apt2);
              SetScreen;
              MoveTo(HookPt1.h, HookPt1.v);
              LineTo(HookPt2.h, HookPt2.v);
              if kind = Dplx then
                gNodeArr[id]^.LList[j] := theLElement;
            end;
          DrawArrows(theLElement);
          ResetScreen;
          gNodeArr[gFirstID]^.LList[i] := theLElement;
          gNumLinks := gNumLinks + 1;
          gLinkArr[gNumLinks] := theLElement
        end
    end
  end
else
  begin
    New(theElement);
    theElement^.Loc.left := thePoint.h + gOrigin.h - 8;
    theElement^.Loc.top := thePoint.v + gOrigin.v - 8;
    theElement^.Loc.right := thePoint.h + gOrigin.h + 8;
    theElement^.Loc.bottom := thePoint.v + gOrigin.v + 8;
    theElement^.Kind := tkind;
    case tkind of
      Node:
        begin
          StringToRNum(gDlogRec.SimStrArr[Npd], theElement^.Pd);
```

```
          ih := GetIcon(NODE_ICON)
        end;
       Hub:
        begin
          StringToRNum(gDlogRec.SimStrArr[Hpd], theElement^.Pd);
          ih := GetIcon(HUB_ICON)
        end;
       Bypass:
        begin
          StringToRNum(gDlogRec.SimStrArr[Bpd], theElement^.Pd);
          ih := GetIcon(BYP_ICON)
        end
     end;
     theElement^.ID := gNumNodes + 1;
     theElement^.Alive := TRUE;
     for i := 0 to MAX_ITEMS do
      theElement^.LList[i] := nil;
     thePoint := theElement^.Loc.topLeft;
     thePoint.h := thePoint.h - gOrigin.h;
     thePoint.v := thePoint.v - gOrigin.v;
     if findElem(thePoint) <> 0 then
      erro := TRUE;
     thePoint := theElement^.Loc.botRight;
     thePoint.h := thePoint.h - gOrigin.h;
     thePoint.v := thePoint.v - gOrigin.v;
     if findElem(thePoint) <> 0 then
      erro := TRUE;
     thePoint.h := theElement^.Loc.right - gOrigin.h;
     thePoint.v := theElement^.Loc.top - gOrigin.v;
     if FindElem(thePoint) <> 0 then
      erro := TRUE;
     thePoint.h := theElement^.Loc.Left - gOrigin.h;
     thePoint.v := theElement^.Loc.Bottom - gOrigin.v;
     if FindElem(thePoint) <> 0 then
      erro := TRUE;
     if thePoint.h < (gPadWindow^.portRect.left + TOOL_SIZE) then
      erro := TRUE;
     if theElement^.Loc.top < (gPadWindow^.portRect.top) then
      erro := TRUE;
     if (gNumNodes < MAX_ITEMS) and (not erro) then
      begin
       gNumNodes := gNumNodes + 1;
       gNodeArr[gNumNodes] := theElement;
       SetScreen;
       PlotIcon(theElement^.Loc, ih);
       ResetScreen
      end
     else
      dispose(theElement)
   end
 end;

{/******************    FindLink    ***********/}
```

```
 function findLink (thisNode, thatNode: ElementPtr): LinkPtr;
  var
   i: integer;
 begin
  i := 1;
  findLink := nil;
  while thisNode^.LList[i] <> nil do
   begin
    if thisNode^.LList[i]^.End2 = thatNode then
     findLink := thisNode^.LList[i];
    i := i + 1
   end
 end;


{/***************ElimLink******************/}
 procedure ElimLink (theLink: LinkPtr);
  var
   i: integer;
   Flag: boolean;
   thisLink: LinkPtr;
 begin
  i := 1;
  Flag := FALSE;
  while i <= gNumLinks do
   begin
    if ((not Flag) and (gLinkArr[i] = theLink)) then
     begin
      thisLink := gLinkArr[i];
      Flag := TRUE
     end;
    if Flag then
     gLinkArr[i] := gLinkArr[i + 1];
    i := i + 1
   end;
  if flag then
   Dispose(theLink);
  gNumLinks := gNumLinks - 1
 end;

{/****************     DetachLink     ***********/}
 procedure DetachLink (theLink: LinkPtr; theNode: ElementPtr);
  var
   i: integer;
   flag: boolean;
 begin
  i := 1;
  flag := FALSE;
  while theNode^.LList[i] <> nil do
   begin
    if theNode^.LList[i] = theLink then
     Flag := TRUE;
    if flag then
```

```
      theNode^.LList[i] := theNode^.LList[i + 1];
     i := i + 1
    end
  end;

{/**************** EraseLink ************/}
  procedure EraseLink (theLink: LinkPtr; thisNode, thatNode: ElementPtr);
   var
    ih: Handle;
  begin
   SetScreen;
   PenPat(white);
   DrawArrows(theLink);
   MoveTo(theLink^.HookPt1.h, theLink^.HookPt1.v);
   LineTo(theLink^.HookPt2.h, theLink^.HookPt2.v);
   ih := GetIcon(NODE_ICON + ord(thisNode^.kind) - ord(Node));
   PlotIcon(thisNode^.Loc, ih);
   ih := GetIcon(NODE_ICON + ord(thatNode^.kind) - ord(Node));
   PlotIcon(thatNode^.Loc, ih);
   ResetScreen;
   PenNormal
  end;

{/************ CutElem **************/}
  procedure CutElem (link: boolean; ID1, ID2: integer);
   var
    pt1, pt2: Point;
    i, j, k: integer;
    anLink: LinkPtr;
  begin

   if link then
    begin
     anLink := nil;
     anLink := findLink(gNodeArr[ID1], gNodeArr[ID2]);
     if anLink = nil then
      anLink := findLink(gNodeArr[ID2], gNodeArr[ID1]);
     if anLink <> nil then
      begin
       DetachLink(anLink, gNodeArr[ID1]);
       DetachLink(anLink, gNodeArr[ID2]);
       EraseLink(anLink, gNodeArr[ID1], gNodeArr[ID2]);
       ElimLink(anLink)
      end
    end
   else
    begin
     if ID1 <> 0 then
      begin
       for i := 1 to gNumNodes do
        begin
         j := 0;
         if i <> ID1 then
```

```
          j := NumLinks(i, ID1);
          for k := 1 to j do
            CutElem(ALINK, ID1, i)
        end;
      SetScreen;
      EraseRect(gNodeArr[ID1]^.Loc);
      ResetScreen;
      Dispose(gNodeArr[ID1]);
      for i := ID1 to gNumNodes + 1 do
        begin
          gNodeArr[i] := gNodeArr[i + 1];
          if gNodeArr[i] <> nil then
            gNodeArr[i]^.ID := i
        end;
      gNumNodes := gNumNodes - 1
    end
  end
end;

{/* * * * * * * * * * * * * * HandleFileChoice * * * * * * * * * * * * * * * * * * * * */}

procedure HandleFileChoice (theItem: integer);
  var
    reply: SFReply;              { used in all SF samples }
    fptr: AFilePtr;
    f: ArchFile;
    r: ArchRec;
    n: ElementPtr;
    l: LinkPtr;
    k: ElemType;
    p: Point;
    typeList: SFTypeList;        { typelist for all SF samples }
    nl, nn: longint;
    i: integer;
begin
  case (theItem) of
    LOAD_ITEM:
      begin
        SFGetFile(Point($00400040), 'Space for Rent', nil, -1, typeList, nil, reply);
                      {location}
                      {vestigial string}
                      {fileFilter}
                      {numtypes; -1 means all}
                      {array to types to show}
                      {dlgHook}
                      {record for returned values}
        if reply.good then
          begin
            Reset(f, concat(PathnameFromWD(reply.vRefNum), reply.fName));
            r := f^;
{get(f);}
            Close(f);
            nn := gNumNodes;
```

```
        for i := nn downto 1 do
          CutElem(NOT_ALINK, i, 0);        {destroy old arch}
        gOrigin.h := 0;
        gOrigin.v := 0;
        SetCtlValue(gHScroll, 0);
        SetCtlValue(gVScroll, 0);

        nn := r.NumNodes;
        nl := r.NumLinks;
        gDlogRec := r.DlogRec;
        RestoreSettings(gSimDlogPtr);
        RestoreSettings(gOutDlogPtr);

        for i := 1 to nn do
          begin
            p := r.NodeArr[i].Loc.topLeft;
            p.h := p.h + 8;
            p.v := p.v + 8;
            AddElem(r.NodeArr[i].Kind, p);
            gNodeArr[i]^.Pd := r.NodeArr[i].Pd;
          end;
        for i := 1 to nl do
          begin
            k := r.LinkArr[i].kind;
            p := gNodeArr[r.LinkArr[i].End1ID]^.Loc.topLeft;
            AddElem(k, p);
            p := gNodeArr[r.LinkArr[i].End2ID]^.Loc.topLeft;
            AddElem(k, p);
            gLinkArr[i]^.Pd := r.LinkArr[i].Pd;

          end;

        UpdateWindow(gPadWindow)
      end
    else
      SysBeep(1)

  end;
 SAVE_ITEM:
  begin
    SFPutFile(Point($00400040), 'Save Topology as:', 'untitled.arch', nil, reply);    {location}
{prompt string}
                        {original name}
                          {dlgHook}
                        {record for returned values}
    If reply.good then
      begin
        for i := 1 to gNumNodes do
          begin
            r.NodeArr[i].Kind := gNodeArr[i]^.Kind;
            r.NodeArr[i].Loc := gNodeArr[i]^.Loc;
            r.NodeArr[i].Pd := gNodeArr[i]^.Pd
          end;
```

```
        for i := 1 to gNumLinks do
         begin
          r.LinkArr[i].Kind  :=  gLinkArr[i]^.Kind;
          r.LinkArr[i].End1ID  :=  gLinkArr[i]^.End1ID;
          r.LinkArr[i].End2ID  :=  gLinkArr[i]^.End2ID;
          r.LinkArr[i].Pd  :=  gLinkArr[i]^.Pd;
         end;
        r.NumNodes := gNumNodes;
        r.NumLinks := gNumLinks;
        r.DlogRec := gDlogRec;
        f^ := r;
        rewrite(f, concat(PathnameFromWD(reply.vRefNum), reply.fName));
        put(f);
        close(f)
       end
      else
       SysBeep(1)
     end;
    QUIT_ITEM:
     gDone := TRUE;
   end
  end;

{/****************           UpdateArch***********************/}
 procedure UpdateArch;
  var
   i: integer;
 begin
  if gDlogRec.SimRadArr[Typ] then
   begin
    for i := 1 to gNumNodes do
     case gNodeArr[i]^.kind of
      Node:
       StringToRNum(gDlogRec.SimStrArr[Npd], gNodeArr[i]^.Pd);
      Hub:
       StringToRNum(gDlogRec.SimStrArr[Hpd], gNodeArr[i]^.Pd);
      Bypass:
       St...igToRNum(gDlogRec.SimStrArr[Bpd], gNodeArr[i]^.Pd)
     end;
    for i := 1 to gNumLinks do
     case gLinkArr[i]^.kind of
      Dplx:
       StringToRNum(gDlogRec.SimStrArr[Dpd], gLinkArr[i]^.Pd);
      Splx:
       StringToRNum(gDlogRec.SimStrArr[Spd], gLinkArr[i]^.Pd)
     end
   end
 end;

{/********************          BypassSet       ************************/}
 function BypassSet (var nset: NodeSet): NodeSet;
  var
   i: integer;
```

```
    theSet: NodeSet;
  begin
   theSet := [];
   nset := [];
   for i := 1 to gNumNodes do
    if gNodeArr[i]^.kind = Bypass then
     theSet := theSet + [gNodeArr[i]^.ID]
    else
     nset := nset + [gNodeArr[i]^.ID];
   BypassSet := theSet
  end;

{/************************      Start      ****************/}
 function Start (FrItem, RngItem: DlogItemType): integer;
  var
   r: real;
 begin
  with gDlogRec do
   begin
    if SimRadArr[RngItem] then
     begin
      StringToRNum(SimStrArr[FrItem], r);
      if r = 0 then
       Start := 0
      else
       Start := 1
     end
    else
     Start := 1
   end
 end;

{/*********************      Fin      ***********************/}
 function Fin (FrItem, RngItem: DlogItemType): integer;
  var
   i: integer;
   r: real;
 begin
  with gDlogRec do
   begin
    if SimRadArr[RngItem] then
     begin
      StringToRNum(SimStrArr[succ(FrItem)], r);
      i := round(r * 1000);
      StringToRNum(SimStrArr[FrItem], r);
      i := i - round(r * 1000);
      StringToRNum(SimStrArr[succ(succ(FrItem))], r);
      if r <> 0 then
       i := i div (round(r * 1000))
      else
       i := 0
     end
    else
```

```
      i := 1;
     Fin := i
    end
  end;

{/*****************      StepSize      *************************/}
 function StepSize (FrItem, RngItem, PdItem: DlogItemType): real;
  var
   r: real;
 begin
  with gDlogRec do
   begin
    if SimRadArr[RngItem] then
     StringToRNum(SimStrArr[succ(succ(FrItem))], r)
    else
     StringToRNum(SimStrArr[PdItem], r);
    StepSize := r
   end
 end;

{/*********************      WriteHeader      *************************/}
 procedure WriteHeader (f: TFilePtr);
 begin
  with gDlogRec do
   begin
    rewrite(f^, concat(PathnameFromDirID(gCurDirStore^, -(gSFSaveDisk^)), OutFileStr));
    writeln(f^, '');
    write(f^, 'NPd');
    if SimRadArr[Hr] then
     write(f^, chr(9), 'HPd');
    if SimRadArr[Br] then
     write(f^, chr(9), 'BPd');
    if SimRadArr[Sr] then
     write(f^, chr(9), 'SPd');
    if SimRadArr[Dr] then
     write(f^, chr(9), 'DPd');
    if OutChkArr[Pseg] then
     write(f^, chr(9), 'Pseg');
    if OutChkArr[Avsl] then
     write(f^, chr(9), 'Avsl');
    if OutChkArr[Ecp] then
     write(f^, chr(9), 'Ecp');
    if OutChkArr[Emsl] then
     write(f^, chr(9), 'Emsl');
    writeln(f^)

   end
 end;

{/*****************      AdjustDlogRec      *************************/}
 procedure AdjustDlogRec (Np, Hp, Bp, Sp, Dp: real);
 begin
  with gDlogRec do
```

```
    begin
      RNumToString(Np, SimStrArr[Npd]);
      RNumToString(Hp, SimStrArr[Hpd]);
      RNumToString(Bp, SimStrArr[Bpd]);
      RNumToString(Sp, SimStrArr[Spd]);
      RNumToString(Dp, SimStrArr[Dpd]);
    end
  end;

{/ * * * * * * * * * * * * * * * * * * * HandleAnalChoice * * * * * * * * * * * * * * * / }
  procedure HandleAnalChoice (theItem: integer);
   var
    f: text;
    n, h, b, s, d, l, max, j, k, item: integer;
    dItem: DlogItemType;
    i, Norm: longint;
    itemType: integer;
    itemHandle: Handle;
    theRect, itemRect: rect;
    dun, Turbo: Boolean;
    myString1, myString2: Str255;
    Ns, Hs, Bs, Ss, Ds, Psg: real;
  begin

   dun := FALSE;
   case theItem of
    SIM_ITEM:
     begin
      BringToFront(gSimDlogPtr);
      NumToString(gNumNodes + gNumLinks, myString1);
      GetDItem(gSimDlogPtr, 24, ItemType, ItemHandle, ItemRect);
      SetIText(itemHandle, myString1);
      ShowWindow(gSimDlogPtr);
      while not dun do
       begin
        ModalDialog(nil, item);
        case item of
         1:
          begin
           HideWindow(gSimDlogPtr);
           SaveSettings(gSimDlogPtr);
           UpdateArch;
           dun := TRUE
          end;
         2:
          begin
           HideWindow(gSimDlogPtr);
           RestoreSettings(gSimDlogPtr);
           dun := TRUE
          end;
         25:
          begin
           GetDItem(gSimDlogPtr, Item, itemType, itemHandle, itemRect);
```

```
          If GetCtlValue(ControlHandle(itemHandle)) <> 1 then
            begin
              SetCtlValue(ControlHandle(itemHandle), 1);
              GetDItem(gSimDlogPtr, item + 1, itemType, itemHandle, itemRect),
              SetCtlValue(ControlHandle(itemHandle), 0);

            end
        end;
      26:
        begin
          GetDItem(gSimDlogPtr, item, itemType, itemHandle, itemRect);
          If GetCtlValue(ControlHandle(itemHandle)) <> 1 then
            begin
              SetCtlValue(ControlHandle(itemHandle), 1);
              GetDItem(gSimDlogPtr, item - 1, itemType, itemHandle, itemRect);
              SetCtlValue(ControlHandle(itemHandle), 0);

            end
        end;
      48..49:
        begin
          GetDItem(gSimDlogPtr, item, itemType, itemHandle, itemRect);
          If GetCtlValue(ControlHandle(itemHandle)) <> 1 then
            begin
              SetCtlValue(ControlHandle(itemHandle), 1);
              GetDItem(gSimDlogPtr, item + (+1 - (item mod 48) * 2), itemType, itemHandle, itemRect);
              SetCtlValue(ControlHandle(itemHandle), 0)
            end
        end;
      50..54:
        begin
          GetDItem(gSimDlogPtr, item, itemType, itemHandle, itemRect);
          If GetCtlValue(ControlHandle(itemHandle)) <> 1 then
            begin
              SetCtlValue(ControlHandle(itemHandle), 1);
              GetDItem(gSimDlogPtr, item + 5, itemType, itemHandle, itemRect);
              SetCtlValue(ControlHandle(itemHandle), 0)
            end
        end;
      55..59:
        begin
          GetDItem(gSimDlogPtr, item, itemType, itemHandle, itemRect);
          If GetCtlValue(ControlHandle(itemHandle)) <> 1 then
            begin
              SetCtlValue(ControlHandle(itemHandle), 1);
              GetDItem(gSimDlogPtr, item - 5, itemType, itemHandle, itemRect);
              SetCtlValue(ControlHandle(itemHandle), 0)
            end
        end;
      otherwise
    end
  end
end;
```

```
    OUT_ITEM:
     begin
      BringToFront(gOutDlogPtr);
      ShowWindow(gOutDlogPtr);
      while not dun do
       begin
        ModalDialog(nil, item);
        case item of
         1:
          begin
           HideWindow(gOutDlogPtr);
           SaveSettings(gOutDlogPtr);
           dun := TRUE
          end;
         2:
          begin
           HideWindow(gOutDlogPtr);
           RestoreSettings(gOutDlogPtr);
           dun := TRUE
          end;
         5..8:
          begin
           GetDItem(gOutDlogPtr, item, itemType, itemHandle, itemRect);
           SetCtlValue(ControlHandle(itemHandle), Bitxor(GetCtlValue(ControlHandle(itemHandle)), 1));
          end;
         otherwise
        end
       end
     end;
    RUN_ITEM:
     begin
      with gDlogRec do
       begin
        SetCursor(GetCursor(watchCursor)^^);
        gBypSet := BypassSet(gNodeSet);
        StringToNum(SimStrArr[Mst], gNumStates);
        Turbo := not (OutChkArr[Pseg] or OutChkArr[Avsl] or OutChkArr[Ecp] or OutChkArr[Emsl]);
       end;
      if Turbo then
       begin
        gSegCount := 0;
        randSeed := TickCount;
        TurboLoop;
        Psg := gSegCount / gNumStates;
        SetRect(theRect, 35, 3, 123, 20);
        EraseRect(theRect);
        FrameRect(theRect);
        MoveTo(37, 15);
        RNumToString(Psg, myString1);
        DrawString(concat('Pseg=', myString1));
        ShowCursor
       end
      else
```

```
begin
 WriteHeader(@f);
 Ns := StepSize(Nfr, Nr, Npd);
 Hs := StepSize(Hfr, Hr, Hpd);
 Bs := StepSize(Bfr, Br, Bpd);
 Ss := StepSize(Sfr, Sr, Spd);
 Ds := StepSize(Dfr, Dr, Dpd);
 for n := Start(Nfr, Nr) to Fin(Nfr, Nr) do
  for h := Start(Hfr, Hr) to Fin(Hfr, Hr) do
   for b := Start(Bfr, Br) to Fin(Bfr, Br) do
    for s := Start(Sfr, Sr) to Fin(Sfr, Sr) do
     for d := Start(Dfr, Dr) to Fin(Dfr, Dr) do
      begin
       AdjustDlogRec(n * Ns, h * Hs, b * Bs, s * Ss, d * Ds);
       UpdateArch;
       gSegCount := 0;
       gAvsl := 0;
       gEcp := 0;
       gEmsl := 0;
       gTotalSegs := 0;
       max := 0;
       randSeed := TickCount;
       for i := 1 to gNumNodes do
        begin
         gSegLnthArr[i] := 0;
         gMaxSegArr[i] := 0
        end;                          {for i to gNumNodes}
       for i := 1 to gNumStates do
        begin

         GetMonteState;
         Analyze;

         if gNumSegs > 1 then
          gSegCount := gSegCount + 1;
         max := 0;
         for j := 1 to gNumSegs do
          begin
           l := SetSize(gSegArr[j]);
           gSegLnthArr[l] := gSegLnthArr[l] + 1;
           if l > max then
            max := l
          end;                        {for j}
         gTotalSegs := gTotalSegs + gNumSegs;
         gMaxSegArr[max] := gMaxSegArr[max] + 1

        end;                          {for i to gNumStates}


       Pag := gSegCount / gNumStates;
       for i := 1 to gNumNodes do
        begin
         gAvsl := gAvsl + i * gSegLnthArr[i];
```

```
            gEcp := gEcp + Binomial(i) * gSegLnthArr[i];
            gEmsl := gEmsl + i * gMaxSegArr[i]
          end;                          {for}

        Norm := (gTotalSegs * SetSize(gNodeSet));
        If Norm <> 0 then
          gAvsl := gAvsl / Norm
        else
          gAvsl := 0;
        Norm := (gTotalSegs * Binomial(SetSize(gNodeSet)));
        If Norm <> 0 then
          gEcp := gEcp / Norm
        else
          gEcp := 0;
        Norm := (gNumStates * SetSize(gNodeSet));
        If Norm <> 0 then
          gEmsl := gEmsl / Norm
        else
          gEmsl := 0;

        with gDlogRec do
          begin
            write(f, n * Ns);
            If SimRadArr[Hr] then
              write(f, chr(9), (h * Hs) : 6 : 3);
            If SimRadArr[Br] then
              write(f, chr(9), (b * Bs) : 6 : 3);
            If SimRadArr[Sr] then
              write(f, chr(9), (s * Ss) : 6 : 3);
            If SimRadArr[Dr] then
              write(f, chr(9), (d * Ds) : 6 : 3);
            If OutChkArr[Pseg] then
              write(f, chr(9), (Psg) : 6 : 3);
            If OutChkArr[Avsl] then
              write(f, chr(9), (gAvsl) : 6 : 3);
            If OutChkArr[Ecp] then
              write(f, chr(9), (gEcp) : 6 : 3);
            If OutChkArr[Emsl] then
              write(f, chr(9), (gEmsl) : 6 : 3);
            writeln(f)
          end;                          {with}

        SetRect(theRect, 35, 3, 123, 20);
        EraseRect(theRect);
        FrameRect(theRect);
        MoveTo(37, 15);
        RNumToString(Psg, myString1);
        DrawString(concat('Pseg=', myString1));
        ShowCursor;
      end;                              {multi for loop}
    close(f)
  end;                                  {else}
SetCursor(arrow)
```

```
    end                                   {RUN}
   end                                    {case}
  end;                                    {procedure}


{/ * * * * * * * * * * ** * * * * * * * * * * HandleMenuChoice * * * * * * * * * * * * * /}

 procedure HandleMenuChoice (menuChoice: longint);
  var
   i, nn, theMenu, theItem: integer;
 begin
  if (menuChoice <> 0) then
   begin
    theMenu := HiWord(menuChoice);
    theItem := LoWord(menuChoice);
    case (theMenu) of
     APPLE_MENU_ID:
      HandleAppleChoice(theItem);
     FILE_MENU_ID:
      HandleFileChoice(theItem);
     EDIT_MENU_ID:
      begin
       case theItem of
        CLEAR_ITEM:
         begin
          nn := gNumNodes;
          for i := nn downto 1 do
           CutElem(NOT_ALINK, i, 0);     {destroy old arch}
          gOrigin.h := 0;
          gOrigin.v := 0;
          SetCtlValue(gHScroll, 0);
          SetCtlValue(gVScroll, 0);
         end;
       end
      end;
     ANAL_MENU_ID:
      HandleAnalChoice(theItem);
    end;
    HiliteMenu(0)
   end

 end;

{/ * * * * * * * * * * * * * * Scroll * * * * * * * * * * * * * * /}

 procedure Scroll;
  var
   oldOrigin: Point;
   dh, dv: integer;
   tRect: Rect;
 begin
```

```
    oldOrigin := gOrigin;
    gOrigin.h := 1 * GetCtlValue(gHScroll);
    gOrigin.v := 1 * GetCtlValue(gVScroll);
    dh := oldOrigin.h - gOrigin.h;
    dv := oldOrigin.v - gOrigin.v;
    gUpdateRgn := NewRgn;
    tRect := gPadWindow^.portRect;
    tRect.right := tRect.right - SBarWidth;
    tRect.bottom := tRect.bottom - SBarWidth;
    tRect.left := tRect.left + TOOL_SIZE + 2;
    ScrollRect(tRect, dh, dv, gUpdateRgn);

{/ * Have scrolled in junk .. . need to redraw * /}

    SetOrigin(gOrigin.h, gOrigin.v);
    OffsetRect(gUpdateRgn^^.rgnBBox, gOrigin.h, gOrigin.v);
    ClipRect(gUpdateRgn^^.rgnBBox);
    DrawCont;
    DisposeRgn(gUpdateRgn);
    SetOrigin(0, 0);
    ClipRect(screenBits.bounds)
  end;


{/ * * * * * * * * * * * * * * * * scrollbarproc * * * * * * * * * * * * * * * * /}

  procedure ScrollProc (theControl: ControlHandle; theCode: integer);
   var
    pageSize: integer;
    scrollAmt: integer;
  begin
   if (theCode <> 0) then
    begin
     if (theControl = gVScroll) then
      pageSize := (gPadWindow^.portRect.bottom - gPadWindow^.portRect.top) div 4
     else
      pageSize := (gPadWindow^.portRect.right - gPadWindow^.portRect.left) div 4;


     case (theCode) of
      inUpButton:
       scrollAmt := -3;
      inDownButton:
       scrollAmt := 3;
      inPageUp:
       scrollAmt := -pageSize;
      inPageDown:
       scrollAmt := pageSize
     end;
     SetCtlValue(theControl, GetCtlValue(theControl) + scrollAmt);
     Scroll
    end
  end;
```

```
{/ * * * * * * * * * * * * * HandleControl * * * * * * * * * * * * * * * * /}
procedure HandleControl (cntrl: ControlHandle; part: integer; pnt: Point);

 begin


  if ((cntrl = gVScroll) or (cntrl = gHScroll)) then
   if (part = inThumb) then
    begin
     part := TrackControl(cntrl, pnt, nil);
     Scroll
    end
   else
    part := TrackControl(cntrl, pnt, @ScrollProc)
 end;


{/ * * * * * * * * * * * * * * * * * * HandleScreen * * * * * * * * * * * * * * * * * * * * * * * * /}
procedure HandleScreen (w: WindowPtr; p: Point);
 var
  thePoint: Point;
  theRect: Rect;
  thePart, ElemID1, ElemID2: integer;
  theControl: ControlHandle;
  savePort: GrafPtr;
  theElement: ElementPtr;
begin
 GetPort(savePort);
 SetPort(w);
 thePoint := p;
 GlobalToLocal(thePoint);
 thePart := FindControl(thePoint, w, theControl);
 ElemID1 := 0;
 ElemID2 := 0;
 theRect := gPadWindow^.portRect;
 theRect.right := theRect.left + TOOL_SIZE;

 if (thePart = 0) then
  begin
   if (PtInRect(thePoint, gTMap[CutNode])) then
    begin
     HiliTool(CutNode)
    end
   else if (PtInRect(thePoint, gTMap[CutLink])) then
    begin
     HiliTool(CutLink)
    end
   else if (PtInRect(thePoint, gTMap[AddDplx])) then
    begin
```

```
      HiliTool(AddDplx)
     end
    else if (PtInRect(thePoint, gTMap[AddSplx])) then
     begin
      HiliTool(AddSplx)
     end
    else if (PtInRect(thePoint, gTMap[AddByp])) then
     begin
      HiliTool(AddByp)
     end
    else if (PtInRect(thePoint, gTMap[AddHub])) then
     begin
      HiliTool(AddHub)
     end
    else if (PtInRect(thePoint, gTMap[AddNode])) then
     begin
      HiliTool(AddNode)
     end
    else if PtInRect(thePoint, theRect) then
     begin
      HiliTool(NullCom);
      gFirstClick := True;
      gFirstID := 0
     end
    else
     begin
      gWhenFirstClick := 0;
      case gMode of
       NullCom:
        begin
         ElemID1 := FindElem(thePoint);
         if ElemID1 <> 0 then
          PopElemDLOG(ElemID1)
         else
          begin
           ElemID1 := GetLinkNum(thePoint);
           if ElemID1 <> 0 then
            PopLinkDLOG(ElemID1)
          end
        end;
       AddNode:
        begin
         AddElem(Node, thePoint);
         if gTState <> locked then
          HiliTool(AddNode);
        end;
       AddHub:
        begin
         AddElem(Hub, thePoint);
         if gTState <> locked then
          HiliTool(AddHub);
        end;
       AddByp:
```

```
        begin
         AddElem(Bypass, thePoint);
         If gTState <> locked then
          HiliTool(AddByp);
        end;
       AddSplx:
        begin
         AddElem(Splx, thePoint);
         If ((gTState <> locked) and gFirstClick) then
          HiliTool(AddSplx);
        end;
       AddDplx:
        begin
         AddElem(Dplx, thePoint);
         If ((gTState <> locked) and gFirstClick) then
          HiliTool(AddDplx);
        end;
       CutNode:
        begin
         ElemID1 := FindElem(thePoint);
         If ElemID1 <> 0 then
          CutElem(NOT_ALINK, ElemID1, ElemID2);
         If gTState <> locked then
          HiliTool(CutNode)
        end;
       CutLink:
        begin
         If gFirstClick then
          begin
           gFirstID := FindElem(thePoint);
           If gFirstID <> 0 then
            gFirstClick := FALSE
          end
         else
          begin
           ElemID2 := FindElem(thePoint);
           If ElemID2 <> 0 then
            begin
             If ElemID2 = gFirstID then
              begin
               gFirstID := 0;
               gFirstClick := True
              end
             else
              begin
               CutElem(ALINK, gFirstID, ElemID2);
               gFirstClick := True
              end
            end;
          end;
         If ((gTState <> locked) and gFirstClick) then
          HiliTool(CutLink);
        end
```

```
      end {case}
     end
    end
   else
    HandleControl(theControl, thePart, thePoint);

   SetPort(savePort)

 end;


{/ * * * * * ** * * * * * * * * * * * * * * * * * * * * HandleMouseDown * * * /}

 procedure HandleMouseDown;
  var
   whichWindow: WindowPtr;
   thePart: Integer;
   menuChoice, windSise: longint;
   thePoint: Point;
 begin
  thePart := FindWindow(gTheEvent.where, whichWindow);
  case (thePart) of
   inDesk:
    SysBeep(1);

   inMenuBar:
    begin
     menuChoice := MenuSelect(gTheEvent.where);
     HandleMenuChoice(menuChoice)
    end;

   inSysWindow:
    SystemClick(gTheEvent, whichWindow);

   inDrag:
    DragWindow(whichWindow, gTheEvent.where, gDragRect);

   inGoAway:
    If (TrackGoAway(whichWindow, gTheEvent.where)) then
     gDone := TRUE;

   inGrow:
    Grow(whichWindow, gTheEvent.where);

   inContent:
    If whichWindow <> frontwindow then
     SelectWindow(whichW. dow)
    else
     HandleScreen(whichWindow, gTheEvent.where)
  end
 end;
```

```
{/*************HandleActiv*************/}
 procedure HandleActivate (w: WindowPtr; goingActive: Boolean);
 begin
  If w = gPadWindow then
   begin
    SetPort(w);
    DrawGrowIcon(w);
   end;
  If goingActive then
   begin
    ShowControl(gHScroll);
    ShowControl(gVScroll)
   end
  else
   begin
    HideControl(gHScroll);
    HideControl(gVScroll)
   end
 end;


{/*************HandleEvent*************/}
 procedure HandleEvent;
  var
   aPoint: Point;
   err: integer;
 begin

  case (gTheEvent.what) of

   nullEvent:
    ;
        (* HandleNull ;*)

   mouseDown:
    begin
     HandleMouseDown
    end;
   autoKey:
    ;
   keyDown:
    begin
     gTheEvent.Message := BitAnd(gTheEvent.Message, charCodeMask);
     If BitAnd(gTheEvent.Modifiers, CmdKey) = CmdKey then
      begin
       HandleMenuChoice(MenuKey(Chr(gTheEvent.Message)))
      end
    end;
   updateEvt:
    If (WindowPtr(gTheEvent.message) = gPadWindow) then
     UpdateWindow(gPadWindow)
    else
     begin
```

```
      BeginUpdate(WindowPtr(gTheEvent.Message));
      EndUpdate(WindowPtr(gTheEvent.Message))
     end;

   activateEvt:
    begin
     HandleActivate(gPadWindow, BAND(gTheEvent.Modifiers, activeFlag) = 1)
    end;
   diskEvt:
    begin
     if HiWrd(gTheEvent.message) <> noErr then
      begin
       SetPt(aPoint, DI_LEFT, DI_TOP);
       err := DIBadMount(aPoint, gTheEvent.Message)
      end
    end;
   app4Evt:
    begin
     case BAND(BROTL(gTheEvent.message, 8), $FF) of
      SUSP_RES_MESS:
       begin
        gInBackground := BAND(gTheEvent.Message, RES_MASK) = 0;
        HandleActivate(gPadWindow, not gInBackground)
       end;
      otherwise
     end
    end;
   otherwise
  end
 end;

{/**********      GetGlobMowse      ***********************/}
 procedure GetGlobMowse (var pt: point);
  var
   event: EventRecord;
 begin
{if OSEventAvail(0, event) then}
{pt := event.where}
{else}
{pt := event.where}
  GetMouse(pt);
  LocalToGlobal(pt)
 end;

{/*********************      AdjustCurs******************/}
 procedure AdjustCurs (pt: point; var crgn: RgnHandle);
  var
   window: WindowPtr;
   arrowRgn, activeRgn: RgnHandle;
   pRect: Rect;
   CursID: integer;
 begin
  window := FrontWindow;
```

```
  if (not ginBackground) and (not IsDAWindow(window)) then
   begin
    arrowRgn := NewRgn;
    activeRgn := NewRgn;
    SetRectRgn(arrowRgn, MAX_NEG, MAX_NEG, MAX_POS, MAX_POS);
    if ((gMode <> NullCom)) then
     begin
      if IsAppWindow(window) then
       begin
        SetPort(window);
        SetOrigin(-window^.portBits.bounds.left, -window^.portBits.bounds.top);
        pRect := window^.portRect;
        pRect.left := pRect.left + TOOL_SIZE;
        pRect.right := pRect.right - SBarWidth;
        pRect.bottom := pRect.bottom - SBarWidth;
        RectRgn(activeRgn, pRect);
        SectRgn(activeRgn, window^.visRgn, activeRgn);
        case gMode of
         AddNode..AddByp:
          CursID := ELEM_CURS;
         CutNode:
          CursID := CUT_NODE_CURS;
         AddSplx:
          CursID := ADD_SLNK_CURS;
         AddDplx:
          CursID := ADD_DLNK_CURS;
         CutLink:
          CursID := CUT_LINK_CURS;
         otherwise
        end;
        SetOrigin(0, 0)
       end
     end;
    DiffRgn(arrowRgn, activeRgn, arrowRgn);
    if PtInRgn(pt, activeRgn) then
     begin
      SetCursor(GetCursor(CursID)^^);
      CopyRgn(activeRgn, crgn)
     end
    else
     begin
      SetCursor(arrow);
      CopyRgn(arrowRgn, crgn)
     end;
    DisposeRgn(arrowRgn);
    DisposeRgn(activeRgn)
   end
 end;

{* * * * * * * * * * * * * * * * * * * * * * * * * MainLoop * * * * * * * * * * * * * * * * * * * * }

 procedure MainLoop;
  var
```

```
    gotEvent: boolean;
    cursRgn: RgnHandle;
    mowse: point;
  begin
   mowse.h := 0;
   mowse.v := 0;
   cursRgn := NewRgn;
   FlushEvents(everyEvent, 0);
   gWNEImplemented := (NGetTrapAddress(WNE_TRAP_NUM, ToolTrap) <>
        NGetTrapAddress(UNIMPL_TRAP_NUM, ToolTrap));
   while (gDone = FALSE) do
    begin
     if (gWNEImplemented) then
      begin
       GetGlobMowse(mowse);
       AdjustCurs(mowse, cursRgn);

       gotEvent := WaitNextEvent(everyEvent, gTheEvent, MAXLONGINT, cursRgn)
      end
     else
      begin
       SystemTask;
       gotEvent := GetNextEvent(everyEvent, gTheEvent)
      end;
     if gotEvent then
      begin
       AdjustCurs(gTheEvent.where, cursRgn);
       HandleEvent
      end
    end
  end;

{/*********     MiscInit     **************/}
  procedure MiscInit;
   var
    i: integer;
  begin
   gDone := FALSE;
   gWhenFirstClick := 0;
   gInBackground := FALSE;
   gMode := NullCom;
   for i := 0 to MAX_ITEMS do
    begin
     gNodeArr[i] := nil;
     gLinkArr[i] := nil;
     gNilLinkArr[i] := nil
    end;
   gTState := off;
   gFirstClick := TRUE;
   gFirstID := 0;
   gNumNodes := 0;
   GNumLinks := 0;
   SetCursor(arrow);
```

```
  gLinkSet := [Splx, Dplx];
  gLComSet := [AddDplx, AddSplx, CutLink];
  randSeed := TickCount;
  gSegCount := 0;
  i := SysEnvirons(1, gWorld);
  gSFSaveDisk := PtrToWord(kSFSaveDisk);
  gCurDirStore := PtrToLong(kCurDirStore)
 end;

{/******************DialogInit     *******************/}
 procedure DialogInit;
  var
   i: DlogItemType;
   itemType: integer;
   itemRect: rect;
   itemHandle: Handle;
 begin
  with gDlogRec do
   begin
    gSimDlogPtr := GetNewDialog(SIM_DLOG, nil, POINTER(MOVE_TC_FRONT));
    gOutDlogPtr := GetNewDialog(OUT_DLOG, nil, POINTER(MOVE_TO_FRONT));
    gElemDlogPtr := GetNewDialog(ELEM_DLOG, nil, POINTER(MOVE_TO_FRONT));
    gLinkDlogPtr := GetNewDialog(LINK_DLOG, nil, POINTER(MOVE_TO_FRONT));
    for i := Npd to Emsl do
     case i of
      Mon:
       SimRadArr[i] := TRUE;
      Exh:
       SimRadArr[i] := FALSE;
      Nc..Dc:
       SimRadArr[i] := TRUE;
      Nr..Dr:
       SimRadArr[i] := FALSE;
      Ind:
       SimRadArr[i] := FALSE;
      Typ:
       SimRadArr[i] := TRUE;
      Npd..Bpd:
       RNumToString(DEF_NODE_PD, SimStrArr[i]);
      Spd, Dpd:
       RNumToString(DEF_LINK_PD, SimStrArr[i]);
      Nfr..Dst:
       case ((ord(i) - ord(Npd)) mod 3) of
        0:
         RNumToString(DEF_TO_PD, SimStrArr[i]);
        1:
         RNumToString(DEF_STP_SZ, SimStrArr[i]);
        2:
         RNumToString(DEF_FRM_PD, SimStrArr[i])
       end;
      Mst:
       NumToString(DEF_STATES, SimStrArr[i]);
      Tst:
```

```
        NumToString((gNumLinks + gNumNodes), SimStrArr[i]);
       Pseg..Emsl:
        If i = Pseg then
         OutChkArr[i] := TRUE
        else
         OutChkArr[i] := FALSE;
       otherwise
      end;
    OutFileStr := 'untitled 1';
   end;
  RestoreSettings(gSimDlogPtr);
  RestoreSettings(gOutDlogPtr);
  GetDItem(gSimDlogPtr, 49, itemType, itemHandle, itemRect);
  HiliteControl(ControlHandle(itemHandle), 255);

 end;

{/ * * * * * * * * * * * * * WindowInit * * * * * * * * * * * * * * /}

 procedure WindowInit;
  var
   padRect, vScrollRect, hScrollRect, viewRect: Rect;
   cRgn: RgnHandle;
 begin
  gOrigin.h := 0;
  gOrigin.v := 0;
  gPadWindow := GetNewWindow(BASE_RES_ID, nil, POINTER(MOVE_TO_FRONT));
  SetPort(gPadWindow);
  vScrollRect := gPadWindow^.portRect;
  vScrollRect.left := vScrollRect.right - 15;
  vScrollRect.right := vScrollRect.right + 1;
  vScrollRect.bottom := vScrollRect.bottom - 14;
  vScrollRect.top := vScrollRect.top - 1;
  gVScroll := NewControl(gPadWindow, vScrollRect, 'hi', TRUE, 0, 0, PAD_LIMIT, scrollBarProc, 0);
  hScrollRect := gPadWindow^.portRect;
  hScrollRect.right := hScrollRect.right - 14;
  hScrollRect.left := hScrollRect.left - 1;
  hScrollRect.bottom := hScrollRect.bottom + 1;
  hScrollRect.top := hScrollRect.bottom - 16;
  gHScroll := NewControl(gPadWindow, hScrollRect, 'HO', TRUE, 0, 0, PAD_LIMIT, scrollBarProc, 0);
  gDragRect := screenBits.bounds;
  gDragRect.left := gDragRect.left + DRAG_THRESHOLD;
  gDragRect.right := gDragRect.right - DRAG_THRESHOLD;
  gDragRect.bottom := gDragRect.bottom - DRAG_THRESHOLD;
 end;

{/ * * * * * * * * * * * * * * * * * * * * MenuBarInit * * * * * * * * * * * * * * * * * * * /}

 procedure MenuBarInit;
  var
   myMenuBar: Handle;
 begin
  myMenuBar := GetNewMBar(BASE_RES_ID);
```

```
    SetMenuBar(myMenuBar);
    gAppleMenu := GetMHandle(APPLE_MENU_ID);
    AddResMenu(gAppleMenu, 'DRVR');
    DrawMenuBar
  end;

begin
  MiscInit;
  WindowInit;
  MenuBarInit;
  DialogInit;
  MainLoop
end.
```

MultiEngine Unit

```
unit Engine;

interface

 uses
  ConsVars;
 var
  gSegArr: array[0..MAX_ITEMS] of NodeSet;

 procedure GetMonteState;
 procedure Analyze;
 procedure TurboAnalyze;
 function SetSize (nset: NodeSet): integer;
 procedure TurboLoop;
implementation

 procedure TurboLoop;
  var
   i: longint;
 begin
  for i := 1 to gNumStates do
   begin
    GetMonteState;
    TurboAnalyze;
   end;
 end;



 function SetSize (nset: NodeSet): integer;
  var
   i, j: integer;
 begin
  j := 0;
  for i := 1 to gNumNodes do
   if ((i in nset) and (i in gNodeSet)) then
    j := j + 1;
  SetSize := j
 end;


 procedure GetMonteState;
  var
   rnd: real;
   i: integer;
 begin
  for i := 1 to gNumNodes do
   begin
    rnd := random;
    rnd := abs(rnd);
    rnd := rnd / 32767.001;
    if rnd < gNodeArr[i]^.Pd then
     gNodeArr[i]^.Alive := FALSE
```

```
      else
        gNodeArr[i]^.Alive := TRUE
    end;
   for i := 1 to gNumLinks do
    begin
     rnd := Abs(Random) / 32767.001;
     if rnd < gLinkArr[i]^.Pd then
       gLinkArr[i]^.Alive := FALSE
     else
       gLinkArr[i]^.Alive := TRUE
    end
 end;
 procedure Analyze;
  var
   ParentSet, DoneSet, SegSet: NodeSet;
   ind, SegNum: integer;
   ParentArr:  SetArrayType;
   flag: boolean;

  procedure inspectseg (var pset, lset: NodeSet; thisNode: ElementPtr);
   var
    i:  integer;
    loopset: NodeSet;
    NextNode: ElementPtr;
  begin
   ParentArr[thisNode^.ID] := pset;
   pset := pset + [thisNode^.ID];
   lset := lset + [thisNode^.ID];
   i := 1;
   while (thisNode^.LList[i] <> nil) do
    begin
     if (thisNode^.LList[i]^.Alive) then
      begin
       if thisNode = thisNode^.LList[i]^.end1 then
         NextNode := thisNode^.LList[i]^.end2
       else
         NextNode := thisNode^.LList[i]^.end1;
       if NextNode^.Alive then
        begin
         if NextNode^.ID in pset then
           lset := lset + (pset - ParentArr[NextNode^.ID])
         else
          begin
           if ((thisNode^.LList[i]^.kind = Splx)) then
            begin
             loopset := [];
             inspectseg(pset, loopset, NextNode);
             if lset * loopset = [] then
              begin
               if (((loopset - gBypSet) <> []) and ((loopset * DoneSet) = [])) then
                begin
                 gNumSegs := gNumSegs + 1;
                 gSegArr[gNumSegs] := loopset
```

```
                    end;
                   pset := pset - loopset;
                   DoneSet := DoneSet + loopset
                  end
                 else
                  lset := lset + loopset
                end
               else
                begin
                 inspectseg(pset, lset, NextNode)
                end
              end
            end
          end;
         i := i + 1
        end
      end;
     begin
      Doneset := [];
      ind := 1;
      gNumSegs := 0;
      for ind := 1 to gNumNodes do
       begin
        if (gNodeArr[ind]^.Alive and not (gNodeArr[ind]^.ID in DoneSet) and (gNodeArr[ind]^.kind <> Bypass))
          then {substitute doneset for segset}
         begin
          ParentSet := [];
          SegSet := [];
          SegNum := gNumSegs + 1;
          gNumSegs := SegNum;
          inspectSeg(ParentSet, SegSet, gNodeArr[ind]);
          gSegArr[SegNum] := SegSet;
          DoneSet := DoneSet + SegSet
         end
       end
     end;

     procedure TurboAnalyze;
      label
       1;
      var
       ParentSet, SegSet: NodeSet;
       ind: integer;
       ParentArr: SetArrayType;
       flag: boolean;
      procedure Tinspectseg (var pset, lset: NodeSet; thisNode: ElementPtr);
       var
        i: integer;
        loopset: NodeSet;
        NextNode: ElementPtr;
      begin
       ParentArr[thisNode^.ID] := pset;
       pset := pset + [thisNode^.ID];
```

```
    lset := lset + [thisNode^.ID];
    i := 1;
    while (thisNode^.LList[i] <> nil) do
     begin
      if (thisNode^.LList[i]^.Alive) then
       begin
        if thisNode = thisNode^.LList[i]^.end1 then
         NextNode := thisNode^.LList[i]^.end2
        else
         NextNode := thisNode^.LList[i]^.end1;
        if NextNode^.Alive then
         begin
          if NextNode^.ID in pset then
           lset := lset + (pset - ParentArr[NextNode^.ID])
          else
           begin
            if ((thisNode^.LList[i]^.kind = Splx)) then
             begin
              loopset := [];
              Tinspectseg(pset, loopset, NextNode);
              if lset * loopset = [] then
               begin
                if (loopset - gBypSet) <> [] then
                 begin
                  goto 1
                 end;
                pset := pset - loopset
               end
              else
               lset := lset + loopset
             end
            else
             begin
              Tinspectseg(pset, lset, NextNode);
             end
           end
         end
       end;
      i := i + 1
     end
   end;
  begin
   SegSet := [];
   flag := FALSE;
   for ind := 1 to gNumNodes do
    begin
     if ((gNodeArr[ind]^.Alive) and not (gNodeArr[ind]^.ID in SegSet) and (gNodeArr[ind]^.kind <>
       Bypass)) then
      begin
       if Flag then
        goto 1;
       ParentSet := [];
       TinspectSeg(ParentSet, SegSet, gNodeArr[ind]);
```

```
      Flag := True;
    end
  end;
 Exit(TurboAnalyze);
1 :
 gSegCount := gSegCount + 1
 end;

end.
```